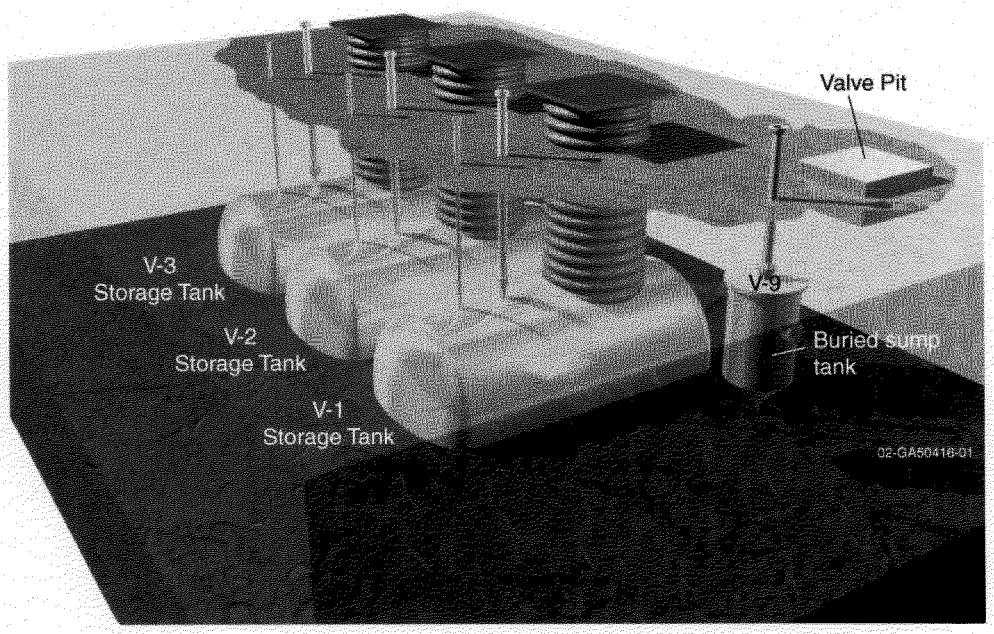
DOE/ID-11038
Revision 0
April 2003
Project No. 22901

U.S. Department of Energy
Idaho Operations Office

Technology Evaluation Report for the V-Tanks, TSF-09/18, at Waste Area Group 1, Operable Unit 1-10



INEEL
Idaho National Engineering and Environmental Laboratory
Name of Science and Engineering Solutions

DOE/ID-11038
Revision 0
Project No. 22901

Technology Evaluation Report for the V-Tanks, TSF-09/18, at Waste Area Group 1, Operable Unit 1-10

Published April 2003

Prepared for the
U.S. Department of Energy
Idaho Operations Office

Technology Evaluation Report for the V-Tanks, TSF-09/18, at Waste Area Group 1, Operable Unit 1-10

DOE/ID-11038
Revision 0
Project No. 22901
April 2003

Approved by

James J. Jessmore
V-Tanks Project Manager

3 April 2003
Date

Gary E. McDannel
WAG 1 Project Engineer

4/3/03
Date

ABSTRACT

This Technology Evaluation Report summarizes the decision analysis process and data used to select a preferred alternative for remedial action of the V-Tanks at the Idaho National Engineering and Environmental Laboratory. The V-Tanks consist of four underground storage tanks that contain sludge and liquid remaining from Test Area North operations between the 1950s and 1980s. The sludge contains a variety of constituents, including radionuclides (such as Cesium-137, Strontium-90, transuranics, and uranium), organics (such as trichloroethane, tetrachloroethane, and polychlorinated biphenyls), and inorganics (such as mercury, cadmium, and lead). In addition to the tank contents, the surrounding soil has been contaminated from spills that occurred while the liquid waste treatment system was operating.

Three technologies were evaluated for treatment of the V-Tank contents: (1) vitrification, (2) thermal desorption, and (3) chemical oxidation/reduction followed by stabilization. Within each technology, alternatives such as in situ, ex situ, and on-Site and off-Site treatment and disposal were considered. Preconceptual designs were completed for each alternative. These designs focused primarily on the threshold criteria of protection of human health and the environment and compliance with applicable or relevant and appropriate requirements under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). To address the balancing criteria that CERCLA outlines, a V-Tanks Decision Support Model was used as an aid in the decision-making process.

From these studies, evaluations, and discussions, ex situ chemical oxidation/reduction followed by stabilization was selected by the Agencies as the preferred alternative for treatment of the V-Tanks' contents. This alternative will remove tank contents and use a chemical oxidant to destroy the organic compounds to below land disposal restriction limits. Then, the waste will be stabilized in containers and disposed of at the INEEL CERCLA Disposal Facility (ICDF). Finally, the surrounding soil, tanks, and debris will be removed and disposed of at the ICDF.

This preferred alternative—ex situ chemical oxidation/reduction followed by stabilization—will be identified in a proposed plan and issued for public input where the two remaining CERCLA criteria of state and community acceptance will be addressed.

CONTENTS

FIGURES

TABLES

ACRONYMS

ARA	Auxiliary Reactor Area
ARAR	applicable or relevant and appropriate requirement
ATG	Allied Technology Group
BEHP	bis(2-ethylhexyl)phthalate
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CFT	contaminant for treatment
CO/S	chemical oxidation/reduction with stabilization
DOE	U.S. Department of Energy
DOE-ID	U.S. Department of Energy Idaho Operations Office
DRE	destruction and removal efficiency
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
ES-CO/S	ex situ chemical oxidation/reduction followed by stabilization
ESV	ex situ vitrification
FY	fiscal year
GAC	granular-activated carbon
HEPA	high-efficiency particulate air
ICDF	INEEL CERCLA Disposal Facility
IDAPA	Idaho Administrative Procedures Act
IDEQ	Idaho Department of Environmental Quality
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
IS-CO/S	in situ chemical oxidation/reduction followed by stabilization

ISV	in situ vitrification
LDR	land disposal restriction
LMITCO	Lockheed Martin Idaho Technologies Company
MACT	maximum achievable control technology
NTS	Nevada Test Site
OR	operational readiness
OU	operable unit
PCB	polychlorinated biphenyl
PCE	tetrachloroethylene
PFD	process flow diagram
PPE	personal protective equipment
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RMERC	roasting or retorting mercury
ROD	Record of Decision
RWMC	Radioactive Waste Management Complex
SD	safety documentation
SGAC	sulfur-impregnated granular-activated carbon
SVOC	semivolatile organic compound
TAN	Test Area North
TCA	trichloroethane
TCE	trichloroethylene
TCLP	toxicity characteristic leaching procedure
TD	thermal desorption
TMV	toxicity, mobility, or volume
TO	thermal oxidizer

TRU	transuranic
TS&D	treatment, storage, and disposal
TSCA	Toxic Substances Control Act
TSDF	Treatment, Storage, and Disposal Facility
TSF	Technical Support Facility
UTS	universal treatment standard
USC	United States Code
VOC	volatile organic compound
WIPP	Waste Isolation Pilot Plant

1. INTRODUCTION

This Technology Evaluation Report summarizes the results of the technology evaluation and comparative analysis processes used to select a new preferred alternative for the V-Tanks' remedial action at Test Area North (TAN), which is one of 10 primary facility areas at the Idaho National Engineering and Environmental Laboratory (INEEL). The three Agencies—the U.S. Department of Energy Idaho Operations Office (DOE-ID), the Idaho Department of Environmental Quality (IDEQ), and the U.S. Environmental Protection Agency (EPA)—decided to evaluate these technologies as replacements for the current alternative in the *Final Record of Decision for Test Area North, Operable Unit 1-10* (DOE-ID 1999a). The current Record of Decision (ROD) alternative is no longer viable, because the off-Site facility capable of treating the waste is no longer available. There is no other facility capable of treating the designated waste stream in accordance with the current ROD alternative.

Three technologies were evaluated:

- Vitrification
  - In situ vitrification (ISV)
  - Ex situ vitrification (ESV)
- Thermal desorption (TD)
  - On-Site desorption with off-Site treatment of off-gas residuals (TD on/off-Site)
  - On-Site desorption with direct treatment of off-gas residuals (TD on-Site)
  - On-Site desorption with off-Site disposal of concentrated solids and off-Site treatment of off-gas residuals (TD off-Site)
- Chemical oxidation/reduction with stabilization (CO/S)
  - In situ chemical oxidation/reduction followed by stabilization (IS-CO/S)
  - Ex situ chemical oxidation/reduction followed by stabilization (ES-CO/S).

The technology evaluation process was performed in accordance with the *Technology Evaluation Scope of Work for the V-Tanks, TSF-09/18, at Waste Area Group 1, Operable Unit 1-10* (DOE-ID 2002a). The technologies evaluated in this report for treating V-Tank waste are vitrification, thermal desorption (TD), and chemical oxidation/reduction stabilization (CO/S). This report provides a comparative analysis of the alternatives against the criteria in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 USC § 9601 et seq.). It selects a preferred alternative to be presented in a new proposed plan. Following public comment on the proposed plan, a new remedy for the V-Tanks will be selected and presented in a ROD amendment. Detailed information about the technology alternatives can be found in the following report: *Pre-Conceptual Designs of Various Alternatives for the V-Tanks, TSF-09/18 at Waste Area Group 1 Operable Unit 1-10* (INEEL 2002a).

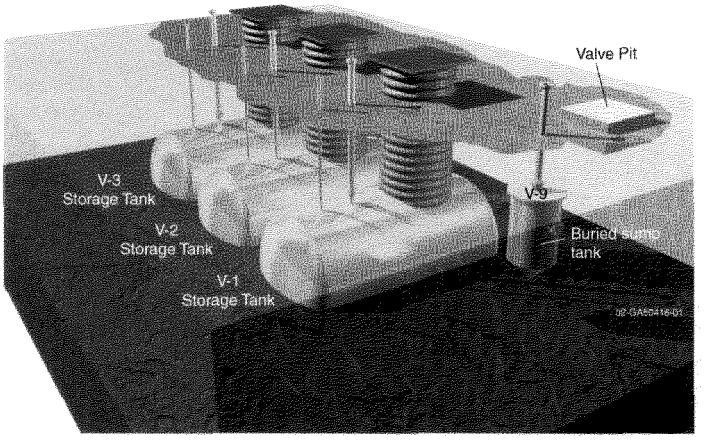


Figure 1. V-Tank configuration.

The V-Tanks discussed in this document are four underground stainless-steel tanks (see Figure 1) installed at the TAN Technical Support Facility (TSF) in the early 1950s as part of a system designed to collect and treat radioactive liquid effluents from TAN operations. These four tanks are identified as Tanks V-1, V-2, V-3, and V-9 and do not have secondary containment. Each of the V-Tanks contains a liquid layer and a sludge layer. The tops of Tanks V-1, V-2, and V-3 (designated as Site TSF-09) are approximately 10 ft below the ground surface (see Figure 2), while the top of Tank V-9 (designated as Site TSF-18) is 7 ft below the ground surface (see Figure 3). The primary focus of the remedial action discussed in this technical report is the treatment and disposal of the tanks' contents. Table 1 summarizes the tanks' capacities and contents.

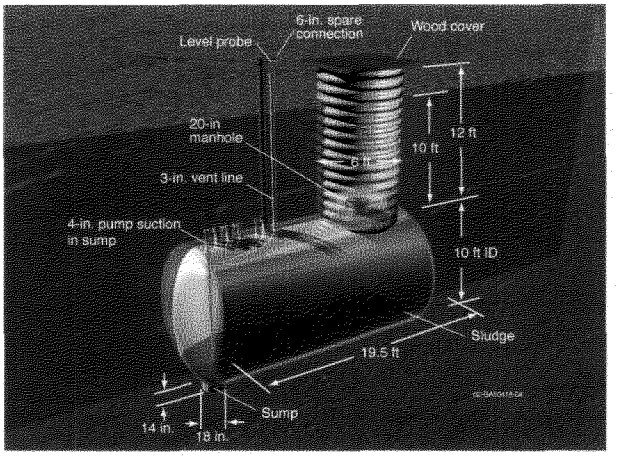


Figure 2. Tanks V-1, V-2, and V-3.

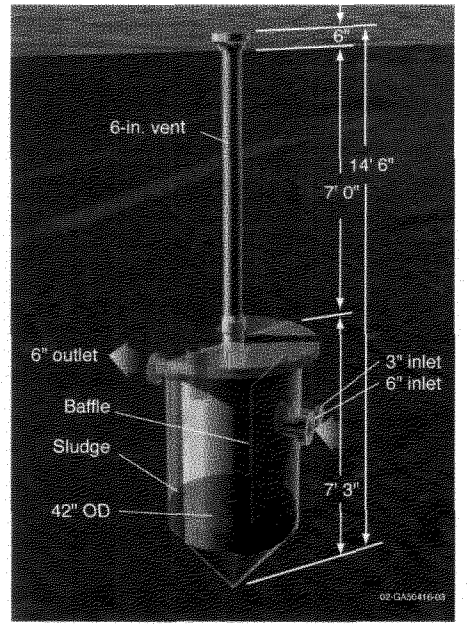


Figure 3. Tank V-9.

Table 1. V-Tank volume in gallons.

Tank	Capacity	Liquid Volume	Sludge Volume	Total Volume
V-1	10,000	1,164	520	1,684
V-2	10,000	1,138	458	1,596
V-3	10,000	7,660	652	8,312
V-9	400	70	250	320
Total	30,400	10,032	1,880	11,912

Remediation of these tanks is an essential element of the INEEL Accelerated Cleanup Project to clean up and close U.S. Department of Energy (DOE) Environmental Management facilities at the INEEL.

The design for the original V-Tanks' remedy in the *Comprehensive Remedial Design/Remedial Action Work Plan for the Test Area North, Waste Area Group 1, Operable Unit 1-10, Group 2 Sites* (DOE-ID 2001) included treating each phase, liquid and sludge, separately. The remedy design included removing and shipping the tank contents to the Allied Technology Group (ATG), which is an out-of-state

commercial treatment (vitrification) facility. However, the facility is no longer available. This made it necessary for the Agencies to consider other treatment alternatives using a focused feasibility study. The alternatives discussed in this report were chosen for evaluation based on a screening level analysis, as discussed in Section 2 of this report. The specific alternatives chosen were:

- Vitrification
  - In situ vitrification (ISV)
  - Ex situ vitrification (ESV)
- Thermal desorption
  - On-Site desorption with off-Site treatment of off-gas residuals (TD on/off-Site)
  - On-Site desorption with direct treatment of off-gas residuals (TD on-Site)
  - On-Site desorption with off-Site disposal of concentrated solids and off-Site treatment of off-gas residuals (TD off-Site)
- Chemical oxidation/reduction with stabilization
  - In situ chemical oxidation/reduction followed by stabilization (IS-CO/S)
  - Ex situ chemical oxidation/reduction followed by stabilization (ES-CO/S).

on-Site = on the INEEL site
off-Site = off the INEEL site

1.1 Contaminants of Concern and Contaminants for Treatment

The original ROD identifies Cs-137 as the only contaminant of concern for the V-Tanks site. However, the INEEL, in conjunction with the regulating agencies, developed a list of contaminants for treatment (CFTs) in order to analyze the chosen alternatives. These CFTs are based on treatment and disposal requirements in accordance with the Resource Conservation and Recovery Act (RCRA) (42 USC § 6901 et seq.) and the waste acceptance criteria of the selected disposal facility(ies). The list of CFTs is presented in Table 2. A detailed discussion of these CFTs relative to the technologies evaluated is provided in the Pre-Conceptual Designs Report (INEEL 2002a).

Table 2. V-Tank contaminants for treatment.

V-Tank Contaminants for Treatment	
Inorganics	**Volatile Organic Compounds**
Antimony (Sb)	Tetrachloroethylene (PCE)
Arsenic (As)	1, 1, 1—Trichloroethane
Barium (Ba)	Trichloroethylene
Beryllium (Be)	
Cadmium (Cd)	**Semivolatile Organic Compounds**
Chlorides (Cl)	bis (2-ethylhexyl) phthalate
Chromium (Cr)	Polychlorinated biphenyls
Lead (Pb)	
Mercury (Hg)	**Radionuclides**
Nickel (Ni)	Cesium (Cs-137)
Silver (Ag)	Strontium (Sr-90)
	Transuranics[a]

a. Includes plutonium (Pu-238 and Pu-239/240), americium (Am-241), curium (Cm-243/244), and neptunium (Np-237).

Table 3 provides the composition of each V-Tank and the overall weighted average for each CFT, as well as other major constituents. Table 3 also includes two columns under the "Tank V-3" and "Average" tank concentration headings. One column under each of these headings provides information about current V-3 and average tank concentrations, while the other column under each of these headings provides V-3 and average tank concentrations after 6,000 gal of supernatant has been removed from Tank V-3.

The mass balances described and referenced in these reports are based on the assumption that 6,000 gal of liquid supernatant was removed from Tank V-3 before initiating the various technologies. However, removal of this liquid might not be completed if the preferred alternative is ultimately selected. The impact on the comparative analysis is inconsequential with or without removal of this liquid.

1.2 Assumptions

The assumptions that have been used for the technology evaluation and comparative analysis that are addressed in this report are listed in Section 1.2.1. In addition, Section 1.2.2 lists the assumptions for treatment.

1.2.1 Characterization Assumptions for the V-Tank Waste Contents

The following are characterization assumptions for the V-Tank waste contents:

- Waste in the V-Tanks has undergone previous RCRA characterization. The V-Tank contents are characterized as RCRA code F001, due to the spent halogenated solvent (trichloroethylene [TCE]) used in degreasing during TAN operations.

- The V-Tank waste is characteristically hazardous, which invokes the full list of underlying hazardous constituents. Therefore, for example, polychlorinated biphenyls (PCBs) require treatment to the 10-ppm land disposal restriction (LDR) limit, and bis(2-ethylhexyl)phthalate (BEHP) requires treatment to the 28-ppm LDR limit for disposal of the primary waste form at the INEEL CERCLA Disposal Facility (ICDF).

- All secondary waste from each treatment alternative will be characterized as F001 listed due to the "derived-from" rule.

- Primary and secondary waste (F001 listed) that meets LDRs will be considered for disposal at the ICDF.

- Secondary waste (F001 listed) that does not meet LDRs and that cannot be practically treated on-Site, in accordance with the treatment alternative mass balances (see Section 3), will be sent off-Site for treatment and/or disposal.

1.2.2 Assumptions for Treatment

The following are treatment assumptions:

- For comparative analysis purposes, all proposed remediation technologies will be initiated after 6,000 gal of liquid supernatant has been removed from Tank V-3.

- The ICDF will open in July 2003 and will be available to receive V-Tank waste in 2005, when the remedial action is projected to take place.

- The Agencies will approve the applicable or relevant and appropriate requirements (ARARs) associated with RCRA alternative treatment standards and Toxic Substances Control Act (TSCA) risk-based petitions (see Section 5.2).

- Design and treatment operations will be performed to meet "clean closure" requirements.

- The ATG will remain a nonviable alternative for treatment of the V-Tanks' waste. No other off-Site treatment will be available before 2005.

- Delisting of the V-Tank contents as hazardous waste will not be pursued.

- The Nevada Test Site (NTS) or Hanford will be accepting out-of-state mixed waste for treatment/disposal by 2007.

- The Waste Isolation Pilot Plant (WIPP) will be accepting remote-handled waste by 2007.

- Soil additions for various treatment alternatives (e.g., vitrification and thermal desorption) are acceptable to ensure proper process operations.

- Thermal desorption is approved by the EPA as a type of retort.

- Macroencapsulation can be performed on those off-gas units that are not granular in form (such as high-efficiency particulate air [HEPA] filters), provided other waste acceptance criteria are met (e.g., less than 500 ppm total organic carbon for the ICDF).

- Macroencapsulation cannot be performed on those off-gas units that are granular in form (such as granular-activated carbon [GAC] and sulfur-impregnated granular-activated carbon [SGAC] filters). As a result, they can only be disposed of at the ICDF if they meet LDRs.

- Organic destruction efficiencies demonstrated during treatability studies (INEEL 1998) will be achieved during actual chemical oxidation/reduction of V-Tank waste.

- V-Tank waste is considered a single waste stream for the purposes of establishing necessary treatment requirements.
- TAN-616 will be removed down to its foundation by the time remediation is initiated.
- Buildings surrounding TSF-09 and TSF-18a (other than TAN-616) will not be affected by the remedial action and removal of TAN-616.
- The contents of all four V-Tanks can be slurried and removed without additional liquid.
- Equipment for transferring the slurried V-Tank sludge and liquid phases will require temporary shielding and secondary containment. Equipment used for decanting V-Tank liquid, before slurrying, only requires secondary containment.
- Maximum achievable control technology (MACT) emission standards only apply to the off-gas treatment system used for the vitrification and thermal desorption on-Site alternatives.
- Contamination control during excavation of contaminated soil can be managed by maintaining slightly damp soil conditions, placing wind restrictions on operations, using temporary tarps, etc., as opposed to large temporary containment structures.
- All equipment coming in contact with the waste or its residuals during processing might have to be disposed of at the ICDF as debris. However, an effort will be made to recover or reuse as much of this equipment as possible before disposing of it as debris waste.

a. Tanks V-1, V-2, and V-3 have an Operable Unit 1-10 CERCLA Site identifier of TSF-09, while Tank V-9 has the identifier of TSF-18.

Table 3. Major components and contaminants for treatment (concentration mg/kg or nCi/g).

Component	Tank V-1	Tank V-2	Tank V-3 As Is	Tank V-3 6,000 gal of Liquid Removed	Tank V-9	Average As Is	Average[a] 6,000 gal of Liquid Removed
Inorganics							
Aluminum (Al)	5.27E+02	1.12E+03	2.58E+02	9.23E+02	2.69E+03	4.82E+02	9.67E+02
Antimony (Sb)	5.13E+00	5.35E+00	9.57E-01	3.43E+00	1.15E+01	2.44E+00	4.90E+00
Arsenic (As)	3.00E+00	3.45E+00	8.58E-01	3.08E+00	3.05E+00	1.48E+00	3.15E+00
Barium (Ba)	4.33E+01	3.80E+01	1.15E+01	4.13E+01	2.99E+02	2.79E+01	5.62E+01
Beryllium (Be)	8.31E+00	4.24E+00	1.49E+00	5.33E+00	2.02E+01	3.36E+00	6.75E+00
Cadmium (Cd)	2.02E+01	2.27E+01	5.09E+00	1.82E+01	2.18E+01	1.01E+01	2.02E+01
Calcium (Ca)	1.78E+03	2.24E+03	6.90E+02	2.34E+03	6.75E+03	1.23E+03	2.42E+03
Chlorides (Cl)[b]	2.08E+02	1.02E+02	7.42E+01	6.90E+01	3.97E+02	1.06E+02	1.36E+02
Chromium (Cr)	5.26E+02	1.12E+03	2.58E+01	9.23E+01	1.88E+03	2.97E+02	5.96E+02
Iron (Fe)	2.63E+03	5.58E+03	1.61E+03	5.77E+03	1.46E+04	2.67E+03	5.35E+03
Lead (Pb)	2.55E+02	3.03E+02	7.27E+01	2.60E+02	4.54E+02	1.41E+02	2.82E+02
Magnesium (Mg)	2.64E+03	2.24E+03	9.81E+02	3.47E+03	9.01E+03	1.62E+03	3.23E+03
Manganese (Mn)	7.02E+02	2.23E+03	3.23E+02	1.15E+03	4.27E+03	7.48E+02	1.50E+03
Mercury (Hg)	2.05E+02	1.16E+02	5.16E+01	1.85E+02	1.67E+03	1.29E+02	2.59E+02
Nickel (Ni)	8.14E+01	7.60E+01	2.39E+01	8.52E+01	3.19E+02	4.77E+01	9.54E+01
Phosphorous (P)	9.63E+03	1.34E+04	4.19E+03	1.50E+04	4.04E+04	7.26E+03	1.45E+04
Silicon (Si)	2.10E+04	2.23E+04	6.13E+03	2.19E+04	7.07E+04	1.23E+04	2.46E+04
Silver (Ag)	3.52E+01	5.05E+01	6.96E+00	2.49E+01	5.22E+02	3.19E+01	6.39E+01
Zinc (Zn)	4.46E+03	4.17E+02	3.74E+02	1.34E+03	1.41E+03	9.87E+02	1.98E+03
VOCs							
PCE	4.38E+02	1.38E+02	3.63E+01	1.30E+02	4.25E+02	1.18E+02	2.37E+02

Table 3. (continued).

Component	Tank V-1	Tank V-2	Tank V-3 As Is	Tank V-3 6,000 gal of Liquid Removed	Tank V-9	Average As Is	Average[a] 6,000 gal of Liquid Removed
TCA	3.14E-01	1.56E-01	4.90E-02	1.59E-01	1.77E+03	5.22E+01	1.05E+02
TCE	3.85E+00	3.62E-01	2.34E-01	2.95E-01	1.45E+04	4.26E+02	8.54E+02
SVOCs							
BEHP	9.19E+02	5.86E+02	3.38E+02	1.21E+03	3.45E+02	4.54E+02	9.10E+02
Aroclor-1260	3.46E+01	2.44E+01	9.99E+00	3.58E+01	9.59E+01	1.79E+01	3.59E+01
Radionuclides							
Cs-137 (nCi/g)	1.74E+03	1.81E+03	5.28E+02	1.88E+03	4.48E+03	9.88E+02	1.98E+03
Sr-90 (nCi/g)	1.52E+03	3.20E+03	1.51E+03	5.36E+03	5.18E+03	1.84E+03	3.68E+03
Transuranics (nCi/g)	1.10E+01	4.02E+00	2.03E+00	7.29E+00	2.64E+01	4.27E+00	8.57E+00
Other							
Total Carbon[c]	1.67E+04	3.33E+04	7.99E+03	2.85E+04	9.19E+03	1.27E+04	2.53E+04

a. Average concentrations are calculated using a weighted average based on tank mass.
b. Does not include chlorides from organics.
c. Assumed to be organic carbon.
BEHP = bis(2-ethylhexl)phthalate
PCE = tetrachloroethylene
SVOC = semivolatile organic compound
TCA = trichloroethane
TCE = trichloroethylene
VOC = volatile organic compound

1.3 Remedial Action Objectives

The remedial action objectives (RAOs) identified in the Operable Unit (OU) 1-10 ROD (DOE-ID 1999a) remain in effect. The RAOs were based on the baseline risk assessment in the *Comprehensive Remedial Investigation/Feasibility Study for the Test Area North Operable Unit 1-10 at the Idaho National Engineering and Environmental Laboratory* (DOE-ID 1997). The RAOs for the V-Tanks and surrounding soil remain applicable and include the following:

- Reduce risk from external radiation exposure from Cs-137 to a total excess cancer risk of less than 1 in 10,000 for the hypothetical resident 100 years in the future and the current and future worker
- Prevent release of the V-Tank contents to the environment.

1.4 Remedial Performance Objectives

Remedy performance objectives were developed during the original remedy design to augment and support the RAOs identified in the OU 1-10 ROD (DOE-ID 1999a). These remedy performance objectives were developed based on the original design approach in the OU 1-10 Remedial Design/Remedial Action Work Plan (DOE-ID 2001) and the OU 1-10 ROD requirement to close the site under the State of Idaho "Hazardous Waste Management Act" (Idaho Code § 39-4401 et seq.). The remedy performance objectives identified in the original design remain applicable to the technologies evaluated and include the following:

- Remove the tank contents, tanks, and ancillary lines/equipment
- Remove the components within the site managed under the Voluntary Consent Order
- Characterize the base of the excavations to determine if releases to the environment from the tanks, piping, and ancillary equipment have occurred
- Characterize the nature and extent of soil contamination in the area surrounding the V-Tanks
- Remove contaminated soil above the final remediation goal for Cs-137 (23.3 pCi/g)
- Remove RCRA-hazardous constituents above regulatory limits to facilitate RCRA closure
- Characterize, treat (as required), and dispose of the generated waste.

1.5 Technical and Functional Requirements

A global set of preliminary technical and functional requirements was developed and is applicable to all of the alternatives for processing V-Tank waste. They provide an overview of some of the key requirements that guided the preconceptual design process. The primary waste form refers to the final, treated form of the bulk V-Tank solids (for vitrification and TD) and the combined solids and liquids for CO/S. Specifically, this is the glassified waste form for vitrification, the bottoms residue from the TD unit (after stabilization, if required), and the stabilized (grouted) waste form for CO/S. These technical and functional requirements are summarized as follows:

- Components of the treatment system shall have real-time monitoring capability (pressure, flow, etc.).

- The treatment system shall be capable of operation with available electrical power sources at TAN, or a suitable portable generator shall be provided.
- The treatment system shall have process data collection and storage capability.
- The treatment system shall be capable of removing or immobilizing hazardous constituents such that the final primary waste form meets, or can be treated to meet, Treatment, Storage, and Disposal Facility (TSDF) criteria.
- The treatment system shall be capable of direct or remote operation, as required by radiation levels, and designed to as low as reasonably achievable requirements.
- The treatment system shall have secondary containment, as required by RCRA (42 USC § 6901 et seq.) and shall meet other applicable industrial standards.
- Radiation shielding shall be used (as required) for all waste transfer subsystems, and remote- or semiremote-operating methods will be needed for the transfers. Particular design considerations will be necessary for transferring dry solids to mitigate escape of contaminated fine particles. Grout and waste stabilization systems will require similar design considerations.
- Process streams shall be compatible with the existing V-Tanks or new treatment system components for the maximum estimated duration of the operation.
- Operating personnel and the environment shall be protected against industrial and radiological hazards.
- Suitable on-Site interim storage shall be provided for primary and secondary waste before further treatment or disposal.

1.6 Technology Evaluation Process

1.6.1 History of the V-Tanks' Decision Support Model

In 2000, a methodology for modeling, structuring, scoring, and evaluating remedial alternatives for CERCLA sites (in general) was developed—*INEEL Subsurface Disposal Area CERCLA-Based Technology Screening Model* (INEEL 2000). A decision was made to modify the existing model to be specific to the V-Tanks. First, criteria, subcriteria, and metrics were determined based on EPA CERCLA guidance, the contaminants of concern and CFTs, and the unique challenges of the site. Next, each criterion was weighted according to the importance established by the three Agencies. The resultant V-Tanks' decision support model comprises evaluation measures, value functions, criteria weights, and a mathematical method for scoring each remedial alternative to obtain a quantitative and consistent comparison against CERCLA criteria.

This model was validated with State of Idaho and EPA regulators as well as the DOE-ID. The model uses net present value cost data, implementation data, and performance data to compare remedial alternatives. The method can easily incorporate analysis of key site characterization and performance uncertainties. As new technology effectiveness and cost data become available, the decision support model can be updated periodically to provide remedial alternative evaluation products to DOE-ID, IDEQ, and EPA decision-makers to support key decision milestones.

1.6.2 Technology Evaluation Process

Figure 4 illustrates an overview of the process used for this evaluation and shows how the process will proceed from this point forward. The process had to be altered slightly from that presented in the Technology Evaluation Scope of Work (DOE-ID 2002a) due to the lack of conceptual design information available from vendors. As a result, Bechtel BWXT Idaho, LLC, generated preconceptual designs for the alternatives. These designs were guided by the global technical and functional requirements and RAOs listed in Section 1.3, "Remedial Action Objectives," and Section 1.5, "Technical and Functional Requirements." The designs included process flow diagrams (PFDs) and associated mass balances in sufficient detail to allow development of an approximate schedule and a preconceptual cost estimate (+50%, -30%). The cost estimates consider all pertinent costs (those associated with Remedial Design/Remedial Action Work Plan issuance, waste disposal, historical costs, transportation, etc.) to ensure a comprehensive life-cycle estimate.

Mass balances for the primary and secondary waste streams were developed to ensure compliance with the associated TSDFs' requirements. Sufficient information was developed to evaluate the various technology alternatives relative to the CERCLA criteria. The V-Tanks' decision support model was used to facilitate objective selection of the preferred alternative, as described in Section 5, "Preferred Alternative Presentation and Remedy Selection." The preconceptual design alternatives are described in detail in the following report: *Pre-Conceptual Designs of Various Alternatives for the V-Tanks, TSF-09/18 at Waste Area Group 1 Operable Unit 1-10* (INEEL 2002a).

1.6.3 Technology Evaluation Supporting Documents

The documents that directly support the information presented in this report include:

- *Technology Evaluation Scope of Work for the V-Tanks, TSF-09/18, at Waste Area Group 1, Operable Unit 1-10* (DOE-ID 2002a)—This document provides the initial screening of technologies to be evaluated and the technology evaluation process outline.

- *Pre-Conceptual Designs of Various Alternatives for the V-Tanks, TSF-09/18 at Waste Area Group 1 Operable Unit 1-10* (INEEL 2002a)—This document provides the preconceptual designs for each technology alternative addressed in this report.

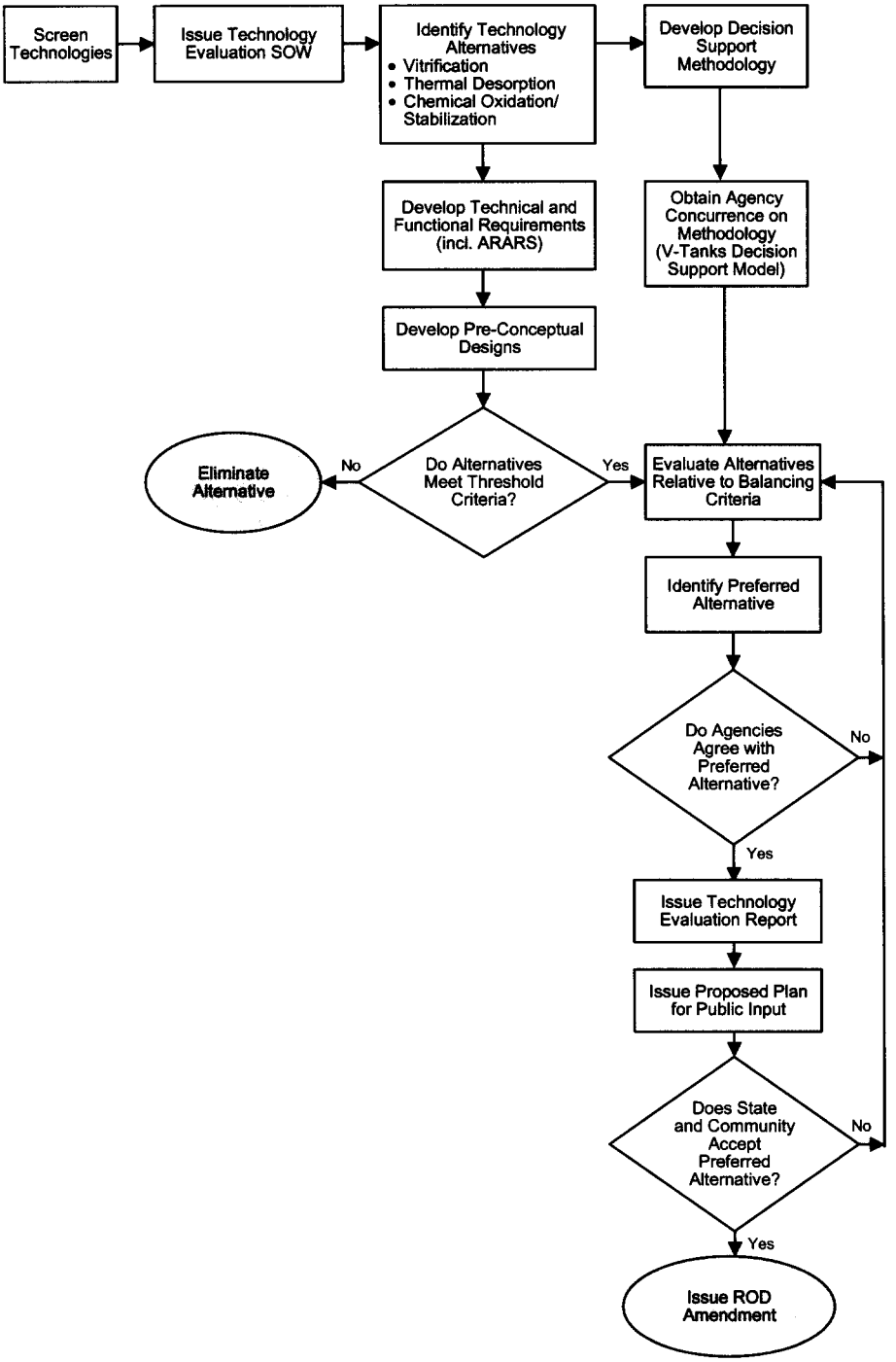


Figure 4. Technology evaluation process flow diagram.

2. IDENTIFICATION AND SCREENING OF TECHNOLOGIES

Since the specified ROD remedy for the V-Tanks (DOE-ID 1999a) was not executable as planned, a reanalysis of viable alternatives was undertaken. The technology evaluation focused on currently viable technologies. Initial screening of technologies is described in the Technology Evaluation Scope of Work (DOE-ID 2002a). To be thorough, technologies previously considered in the Remedial Investigation/Feasibility Study (DOE-ID 1997) also were reviewed, and all technologies that were considered previously or during the current technology evaluation are discussed below.

As described in Section 1, the V-Tanks' contents represent a complex waste stream. This complexity might require use of multiple treatment technologies to ensure that all of the hazardous constituents are properly treated before disposal. In addition to this screening level analysis, the Technology Evaluation Scope of Work (DOE-ID 2002a) outlined various resources and previous evaluations that helped narrow the field of potentially viable technologies.

2.1 No Action

The No Action alternative does not include remedial activities beyond Site access controls and/or environmental monitoring currently conducted at the INEEL as part of Sitewide activities. The No Action alternative does not achieve the RAOs for the V-Tanks, and it was previously excluded. No further discussion of this alternative is provided.

2.2 Institutional Controls

Institutional controls include actions taken by the responsible authorities to minimize potential danger to human health and the environment. Institutional controls are ongoing actions that can be maintained only for as long as the responsible authority is in control of the site. Based on the *Comprehensive Facility and Land Use Plan* (DOE-ID 1996), institutional controls will be maintained for a minimum of 100 years following site closure. While institutional controls may be used to supplement other remedial actions, the RAOs are not achieved solely through these controls. In addition, if current RAOs are achieved, it is expected that institutional controls may not be required. Institutional controls are currently in place for the V-Tanks site, and they will be retained for further consideration (if required) after completion of the remedial action.

2.3 Containment

Containment options for the V-Tanks' contents include capping the tank areas and installing hydraulic barriers. These options are discussed in Sections 2.3.1 and 2.3.2.

2.3.1 Capping

A cap installed above the tank location serves to deter inadvertent intrusion into the tanks or erosion of existing cover materials, and it prevents percolation of precipitation, which could mobilize contaminants in the event the V-Tanks leak. This technology does not eliminate horizontal or downward migration of contaminants from tank leakage. Capping was eliminated from further consideration due to its limited effectiveness in preventing releases of contaminants from the V-Tanks.

2.3.2 Hydraulic Barriers

Horizontal and downward migration of contaminants can be mitigated by installing hydraulic barriers. Hydraulic barrier costs are high, and they could ultimately leak. In addition, the cell created around the V-Tank by the installed barriers could fill with precipitation, which could bring contaminants to the ground surface, unless capped as well. Hydraulic barriers were eliminated from further consideration due to the potential lack of long-term effectiveness and high cost.

2.4 In Situ Treatment

2.4.1 Stabilization

Stabilization could be accomplished by injecting the stabilization reagents directly into the tanks or pumping the tank contents to the surface and then adding appropriate reagents, mixing the contents, and pumping the contents back into the tanks. Reagents might include grout, sand, cement, clays, pozzolans, and/or polymers. The reagents used, and the suitable proportions, would be selected during treatability testing. The mixture would fill the tank and, therefore, would reduce the risk of collapse. The toxicity of the stabilized waste would not be reduced; however, the unit activity would be reduced, thereby reducing the direct radiation exposure. In addition, the contaminants would be less mobile in the event of a tank breach. The cost of in situ stabilization is relatively low.

In situ stabilization alone will not sufficiently reduce contaminant toxicity, mobility, or volume (TMV). Destruction of organics, such as TCE and BEHP, is necessary to achieve LDR total constituent concentration (not toxicity characteristic leaching procedure [TCLP]) limits of 6 ppm and 28 ppm, respectively. Grout alone would have to reduce the total concentration by orders of magnitude, which is not necessary for stabilization, thereby constituting impermissible dilution. Since stabilization does not remove the organic constituents, it is judged ineffective as a standalone treatment. However, it could be effective in stabilizing leachable constituents, such as RCRA metals. It also could be used as an interim measure to minimize the spread of contamination in the event of a breached tank. Stabilization is retained for further analysis, since it could be useful as a component of other alternatives.

2.4.2 Vitrification

Vitrification is achieved by applying large electrical currents to the waste material with graphite electrodes. The area bounded by the electrodes is heated to over 1,400°C and melted. After cooling, the resulting waste form is a leach-resistant, glass-like material similar to obsidian.

If conducted properly, the effectiveness of this option in meeting RAOs is estimated to be high. This option would mitigate the potential risks to human health and the environment by removing and/or destroying the hazardous organics and certain metals and by significantly reducing potential mobility via leaching.

This technology is effective at encapsulating inorganic contamination, with the exception of mercury and cadmium. These metals, and other volatile compounds detected in the tanks, are likely to volatilize and must be captured and/or treated by the vitrification off-gas system. The semivolatile organic compounds (SVOCs), such as PCBs, typically are destroyed during the vitrification process. Vitrification is retained for further evaluation due its effectiveness in treating V-Tank waste.

2.4.3 Chemical Leaching

Leaching is accomplished by introducing solvents or chelating agents into the tank to selectively dissolve or partition contaminants. Chemicals typically used include nitric acid, oxalic acid, or ethylene diaminetetraacetic acid. Since there appears to be no specific advantage in partitioning the contaminants into another liquid phase, chemical leaching was removed from further consideration.

2.4.4 Oxidation/Reduction

Oxidation/reduction processes also can be considered as an in situ treatment for the tank contents. Oxidizing and/or reducing reagents are mixed with the waste to destroy toxic organics or to change the oxidation state of heavy metals. The efficiency of such processes depends on thorough mixing of reagents with the waste, concentrations, contact time, and temperature. An in situ oxidation/reduction process would require testing to optimize. Oxidation alone will not sufficiently reduce the toxicity and mobility of all contaminants, but it could destroy essentially all hazardous organic constituents. Chemical oxidation/reduction is retained for further analysis, since it could be used in combination with another technology.

2.5 Ex Situ Treatment

The ex situ treatment technologies discussed in the following subsections are discussed generally in the context of treating the tank contents on-Site. However, some of these technologies could be used for treating secondary waste, either on-Site or off-Site.

2.5.1 Neutralization

Neutralization is used to treat corrosive and/or reactive waste. Since the tank waste pH is in the range of 7 to 8, neutralization is not required and is eliminated from further consideration.

2.5.2 Oxidation/Reduction

Oxidizing and/or reducing reagents are mixed with the waste to destroy toxic organics or to change the oxidation state of heavy metals. This technology can be applied ex situ after transferring the waste to a vessel designed for this operation. This technology is retained as a possible treatment process for the reasons described for the in situ application.

2.5.3 Steam Reforming

Historically, steam reforming has been applied to waste containing a significant quantity of organic material. It uses superheated steam to reduce the waste before it is burned in a special reactor without oxygen. This technology is being considered for treatment of contact-handled, organic-contaminated transuranic waste and sodium-bearing waste at the INEEL. However, this concept is only in the alternative evaluation phase for these waste streams. Modifying either of these facilities to process V-Tank waste, although possible, would entail substantial cost and would not be a timely alternative. Availability of portable/temporary treatment units is uncertain. Therefore, steam reforming is not considered a feasible technology for the V-Tank waste at this juncture.

2.5.4 Wet Air Oxidation

Wet air oxidation destroys organic waste using an oxidant in water at high temperatures and pressures. Wet air oxidation is eliminated from further consideration due to the limited amount of PCB destruction information and the expected complexity, risk, and cost of the treatment.

2.5.5 Stabilization

As with the in situ case, stabilization alone will not adequately address the organic contaminants; however, combined with other technologies, it may be effective; therefore, it is retained for further analysis.

2.5.6 Amalgamation

This process is used specifically to stabilize mercury as an insoluble compound, such as mercuric sulfide. There are various methods of capturing the mercury and rendering it nonleachable, such as using SGAC. Generally, the amalgamation technology is effective only for mercury and not other contaminants. Amalgamation is retained for further analysis, since it could be used in combination with another technology.

2.5.7 Encapsulation

This process encases the waste in a matrix of polymer, plastics, grout, or asphalt to immobilize solids that contain hazardous metals. Encapsulation alone is not considered a viable treatment for the V-Tank waste, since the V-Tanks contain organic constituents and mercury; however, it could be used to treat the emptied tanks or process equipment before disposal and is, therefore, retained.

2.5.8 Vitrification

Ex situ vitrification is similar to in situ treatment, except that the waste is removed from the tanks and treated. Portable systems have been designed for on-Site applications. As with in situ vitrification, this technology is retained.

2.5.9 Incineration

Incineration is the treatment standard for waste containing PCBs. The technology is commonly used to destroy the organic constituents in the waste, and it is a viable technology for the V-Tank waste. Incineration will reduce the primary waste volume, since the water will be evaporated and treated in the associated off-gas system. The resulting ash and off-gas waste could require immobilization before final disposal. Though this technology is technically acceptable, no facilities are currently available to accept the mixture of materials in the V-Tanks, including mercury, high-chloride-content organic constituents, radionuclides, and transuranics. Furthermore, unlike vitrification, portable systems generally are not available. Therefore, incineration is not retained as an on-Site treatment method. Certain secondary waste streams (e.g., GAC beds) may be amenable to shipment off-Site and subsequent incineration; therefore, off-Site incineration is retained.

2.5.10 Thermal Oxidation

Similar to incineration, thermal oxidation uses elevated temperatures (above 1,000°C), either through direct or indirect heating, to treat organic constituents. Typically, these units are used in conjunction with other thermal treatment processes (e.g., vitrification) to ensure that any hazardous organics that escape the primary treatment are destroyed before atmospheric discharge. Thermal oxidation is retained for further consideration, in combination with other technologies.

2.5.11 Biological

Biological treatment uses bacteria to destroy organic constituents. The technology is most often used on contaminated soil. Inquiries were made concerning the possibility of using this technology to treat the PCBs. This technology would be experimental, since no demonstration has shown successful treatment of PCBs in a liquid waste medium. This technology is not considered feasible at this stage due to its experimental nature.

2.5.12 Separation

Separation processes exploit the waste's physical or chemical properties to partition constituents in a manner that simplifies disposal. Separation should be considered, in combination with other technologies. The technologies are discussed in further detail below.

2.5.12.1 Reverse Osmosis. These types of systems require prefiltration to enable the high solids content in the V-Tank waste to be processed. Since the sludge phase contains the majority of the CFTs, there does not appear to be any advantage in using this system in conjunction with other processes that would be required. Treatment of the filtered liquid phase by reverse osmosis could be conducted, but the contaminants generally are removed more readily by other systems (e.g., GAC filters). The reverse osmosis technology is not retained for further analysis.

2.5.12.2 Ion Exchange. This technology could be used to remove most of the radionuclides in solution. However, the characterization data indicate that most of the radionuclides are associated with the sludge phase, in which ion exchange would have limited effectiveness. Furthermore, the resulting waste product would still contain metals and organics. These constituents would require subsequent treatment. Reduction of the gamma radiation levels could simplify process design; however, this technology will not be considered further due to the anticipated operational difficulties.

2.5.12.3 Thermal Desorption. Thermal desorption is a process used to separate organics (e.g., TCE and PCBs) and low-boiling-point metals (such as mercury) from an inorganic waste stream. If operated in a batch mode, the process can be operated in a vacuum and at relatively low temperatures (300°C). If the tank waste was to be treated with this process, the volatilized components would have to be treated or collected in the off-gas system. Off-gas treatment could include catalytic oxidation or incineration, either on-Site or off-Site. Off-gas condensates also could require further treatment before disposal. Thermal desorption is retained for further consideration in combination with other technologies.

2.5.12.4 Carbon Adsorption. This process removes relatively low concentrations of contaminants (such as organics) from liquid or gas streams. Since the organic and inorganic concentrations in the tank waste are relatively low, this process is viable for secondary waste that is relatively free of solids. As noted earlier, carbon can be impregnated with chemicals, such as sulfur, to effectively remove additional contaminants such as mercury. The spent carbon might need to be treated before disposal. Carbon adsorption is retained as a treatment option to be used with other technologies.

2.5.12.5 Chemical Precipitation. This process is used to change the solubility of a dissolved contaminant by either changing the contaminant to a less soluble form or changing the solvent chemistry to decrease the contaminant solubility. The precipitate is filtered from the treated waste stream, and it requires additional treatment (such as immobilization) before disposal. Since many CFTs are not dissolved, but are associated with the sludge phase, there are limited apparent advantages to precipitation. Therefore, this process is eliminated from further consideration.

2.5.12.6 Centrifuges. These units are used to separate two-phase waste streams such as the V-Tank waste. A one-time application on a limited amount of waste is not likely to be cost effective relative to filtration, so centrifugation is eliminated from further consideration.

2.5.12.7 Filtration. Commonly, filtration is used to separate solids from liquids or gases. The type of filter used depends on the waste characteristics and particle size of the solids. Because of reduced interim storage, transportation, and treatment costs, filtration was selected previously for treatment of the primary waste when off-Site shipment of only the solid phase was planned. Since only on-Site treatment is currently viable for the sludge phase, the need for complete-phase separation is reduced, making simple-phase separation steps (such as decanting) more attractive. As a minimum, filtration of particulates from off-gas streams will be needed with any technology, so filtration is retained.

2.5.12.8 Distillation or Steam Stripping. Distillation or steam-stripping processes are used to remove volatile organics from aqueous waste streams. Since the volatile organic compound (VOC) and SVOC concentrations in the V-Tanks are very low, and they have widely varying vapor pressures, these processes do not appear to offer any advantage over thermal desorption. Therefore, they are eliminated from further consideration.

2.5.12.9 Evaporation. Evaporation can be used to reduce the aqueous waste volume. The process vaporizes the water from the waste, while the less volatile components remain in a concentrate. Since the V-Tank waste contains low-boiling-point VOCs (e.g., TCE), additional treatment of the vaporized organics would be required. Depending on the organic concentrations, treatment could be as complex as oxidation or as simple as carbon adsorption. Since the VOC concentration in the waste is low, evaporation is a viable treatment process, in combination with other technologies. A possible treatment unit is the Process Equipment Waste Evaporator System located at the Idaho Nuclear Technology and Engineering Center (INTEC). The V-Tank sludge does not meet the waste acceptance criteria for process equipment waste, but the liquid phase and/or off-gas condensate streams are likely to be acceptable, possibly with some pretreatment (carbon adsorption). Evaporation is retained for further consideration.

2.6 Contents Removal

Tank contents' removal can be accomplished by remote or semiremote methods. Vacuum devices have been widely used for decontaminating nuclear facilities. Typically, the suction inlet must be moved over the entire surface of the tank to be emptied. If caked solids are present, additional techniques to loosen or slurry the solids could be required (e.g., air jets, liquid jets, mechanical agitation). If slurrying is accomplished, it might be possible to leave the suction inlet in one location, thereby significantly simplifying the activity. The needed vacuum can be supplied by eductor jets (steam, air, or water), various pump types, or hybrid units (such as fluidic jet systems), which slurry and pump materials. Generally, costs are higher for remotely operated equipment due to complexity, including remote viewing/monitoring. Vacuum-based removal is retained for further consideration. Direct removal of the V-Tank contents is precluded by the radiation level in the waste, and it is eliminated from further evaluation.

2.7 Disposal

The INEEL on-Site, private sector off-Site, and federally owned off-Site facilities are considered for disposal.

2.7.1 Idaho National Engineering and Environmental Laboratory On-Site Disposal

Two INEEL facilities are considered for disposal: the Radioactive Waste Management Complex (RWMC) and the ICDF.

2.7.1.1 Disposal at the Radioactive Waste Management Complex. Sections 4.6 and 4.7 of the *Idaho National Engineering and Environmental Laboratory Waste Acceptance Criteria* (DOE-ID 2002b) were reviewed to determine the acceptability of V-Tank CERCLA waste as low-level or mixed low-level waste for disposal.

Section 4.6 of the *Idaho National Engineering and Environmental Laboratory Waste Acceptance Criteria* (DOE-ID 2002b) applies to low-level waste to be stored or disposed of at the INEEL, shipped to an off-Site commercial facility for processing (compaction or sizing), or shipped off-Site for disposal. Since the V-Tank waste is managed as F-listed mixed low-level waste, Section 4.6 of the *Idaho National Engineering and Environmental Laboratory Waste Acceptance Criteria* (DOE-ID 2002b) does not apply, and the V-Tank waste cannot be disposed of at the RWMC. However, if a "no-longer-contained-in" determination or delisting was pursued for any V-Tank waste, then disposal at the RWMC might be a viable option. It is unlikely that these exceptions will be pursued for the V-Tank contents; however, they could possibly be pursued for the soil and some debris.

Section 4.6 of the *Idaho National Engineering and Environmental Laboratory Waste Acceptance Criteria* (DOE-ID 2002b) also prohibits PCBs at concentrations greater than 50 ppm, except for radiologically contaminated PCB bulk-product waste and PCB cleanup waste in accordance with the requirements of 40 *Code of Federal Regulations* (CFR) 761.62 and 40 CFR 761.61(a)(5)(v), respectively. In addition, the RWMC does not accept low-level waste with transuranic (TRU) concentrations greater than 10 nCi/g.

Section 4.7 of the *Idaho National Engineering and Environmental Laboratory Waste Acceptance Criteria* (DOE-ID 2002b) applies to mixed low-level waste shipped to INEEL facilities. This section is only applicable to storage facilities for mixed low-level waste available at the INEEL. The only facility where mixed low-level waste can be disposed of at the INEEL is the ICDF, which is discussed below, and this facility currently is limited to disposal of CERCLA waste. Therefore, no mixed low-level waste can be disposed of at the RWMC. However, V-Tank mixed low-level waste could be temporarily stored at the RWMC, in accordance with the RWMC RCRA permit.

Disposal of low-level waste has been determined to be effective in protecting human health and the environment, and it meets the RAOs. This disposal option is retained for further evaluation to accommodate any low-level waste generated from the V-Tank remedial action or any mixed low-level waste reclassified as low-level waste through appropriate regulatory processes.

2.7.1.2 Disposal at the INEEL CERCLA Disposal Facility. The *Waste Acceptance Criteria for ICDF Landfill* report (DOE-ID 2002c) has been reviewed to determine acceptability of V-Tank CERCLA mixed low-level waste for disposal. Based on this review and the planned completion date for this facility, disposal of some or all of the waste from processing the V-Tank contents—including surrounding soil, tanks, and debris—should be acceptable. Solid PCB remediation waste can be disposed of at the ICDF at concentrations up to 500 ppm. Characteristically hazardous waste from outside the INTEC area of contamination must meet the LDR limit of 10 ppm PCB. The ICDF does not accept TRU waste greater than 10 nCi/g.

Most of the technologies being evaluated will result in waste streams that meet the PCB and transuranic limits for the ICDF. However, certain treatment technologies might produce a waste stream that exceeds the 10-nCi/g TRU limit, thereby requiring other disposal facilities.

2.7.2 Commercial Off-Site Disposal

Only three private sector off-Site disposal facilities are available for CERCLA mixed low-level waste. These facilities are Envirocare of Utah, Barnwell Waste Management Facility, and U.S. Ecology at Hanford. These facilities' waste acceptance criteria were reviewed for the V-Tank waste.

2.7.2.1 Envirocare. Envirocare accepts CERCLA mixed low-level waste for disposal. Currently, the Envirocare Radioactive Material License permits disposal of Class A mixed low-level waste only. Envirocare prepared and received approval from the State of Utah Radiation Control Board for a Radioactive Material License allowing the disposal of Class B and C waste. However, Envirocare currently has withdrawn its application. Some of the treatment technologies evaluated for the V-Tank contents might produce a mixed low-level waste with greater-than-Class A radioactivity levels.

Envirocare can accept PCBs as PCB remediation waste at any concentration preapproved by Envirocare. The Envirocare facility is retained as a feasible location for final waste disposal of any V-Tank CERCLA mixed low-level waste streams with less than Class B and C radioactivity levels.

2.7.2.2 Barnwell Waste Management Facility. The *Barnwell Waste Management Facility Site Disposal Criteria, Chem-Nuclear Systems Barnwell Office* (Chem-Nuclear Systems, LLC, 2002) states that "no PCBs or PCB contaminated *[sic]* items will be accepted for disposal" and that treated hazardous waste will be reviewed for acceptance on a case-by-case basis. If a "no-longer-contained-in" determination or delisting was pursued for any V-Tank waste, then disposal at the Barnwell Waste Management Facility could be a viable option. It is unlikely that these exceptions will be pursued for the V-Tank contents; however, they could possibly be pursued for the soil and some debris, although the transportation costs would likely be prohibitive. Nevertheless, the Barnwell Waste Management Facility is retained as a feasible location for final waste product disposal, since there are PCB treatment processes under consideration that could produce an acceptable waste product.

2.7.2.3 U.S. Ecology Commercial Low-level Radioactive Disposal Facility at Hanford. The commercial low-level radioactive disposal site operated by U.S. Ecology, Inc., only receives low-level waste from off-Site facilities belonging to the Northwest LLW Compac. Class A, B, and C waste is received at this facility; no RCRA waste can be received at this facility. Transuranic waste with concentrations greater than 10 nCi/g must have State of Washington approval before receipt. Some PCB waste is acceptable, with restrictions on container size and volume due to the placement restrictions in the disposal facility. If a "no-longer-contained-in" determination or delisting was pursued for any V-Tank waste, then disposal at the Hanford U.S. Ecology low-level radioactive disposal site could be a viable option. It is unlikely that these exceptions will be pursued for the V-Tank contents, but they could possibly be pursued for the soil and some debris.

2.7.3 Federally Owned Off-Site Disposal

2.7.3.1 Waste Isolation Pilot Plant. Waste destined for the WIPP must be defense-related waste, which would qualify the V-Tank waste since it is defense-related waste. The *Contact-Handled Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant* (DOE/WIPP 2002) states that the lower limit for contact- or remote-handled transuranic waste is 100 nCi/g of transuranic radionuclides. If a waste volume-reduction process (such as evaporation or thermal desorption) is used, production of a concentrate that has a specific activity of more than 100 nCi/g transuranic is feasible. Depending on the treatment process, the WIPP is a possible repository for the final waste form.

2.7.3.2 Hanford Environmental Restoration Disposal Facility. The Environmental Restoration Disposal Facility (ERDF) is the CERCLA disposal facility at Hanford. Review of the *Environmental Restoration Disposal Facility Waste Acceptance Criteria* (Corriveau and Obenauer 1995) indicated the following limitations for accepting the V-Tank waste:

- Solidified organic liquids containing 500 ppm or greater PCBs will not be accepted for disposal
- Currently, ERDF does not accept any waste from outside the Hanford reservation
- Transuranic concentration must be <100 nCi/g.

The ERDF is retained as a feasible location for final waste disposal, since there are PCB treatment processes under consideration that could produce an acceptable waste product, and it is possible that the off-Site restriction could be negotiated.

2.7.3.3 Hanford Mixed Low-Level Burial Grounds Trenches 31 and 34. The *Hanford Site Solid Waste Acceptance Criteria* (Hanford 2002) states that Trenches 31 and 34 of the 218-W-5 Burial Ground are lined RCRA-compliant units for disposal of certain low-level mixed waste. Currently, only low-level waste originally designated with RCRA characteristic numbers D001 through D043 and certain listed waste numbers (F001 through F005, and F039 derived from F001 through F005 waste) are accepted in Trenches 31 and 34. All waste accepted at Trenches 31 and 34 must meet the applicable LDR treatment standards of 40 CFR 268, "Land Disposal Restrictions," and Waste Acceptance Criteria 173-303-140. Prohibited waste includes TSCA-regulated PCB waste—except as specifically authorized by 40 CFR 761, "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions," and waste generated from CERCLA cleanup activities—unless specific approval (e.g., a ROD) has been granted by the EPA to manage the waste on the Hanford Site. The waste's TRU content cannot exceed 100 nCi/g. Currently, Trenches 31 and 34 are managed by Fluor Hanford, which does not accept off-Site mixed low-level waste. However, this site will be retained as a possible disposal facility, since receipt of the V-Tank waste could be negotiated.

2.7.3.4 Nevada Test Site. The *Nevada Test Site Waste Acceptance Criteria* (NTS 2002) states that only dewatered bulk PCB remediation waste with <50 ppm of PCBs is accepted for disposal. The waste's TRU concentration must not exceed 100 nCi/g. Currently, the NTS does not accept off-Site mixed low-level waste. However, negotiations currently are in progress to allow receipt of off-Site mixed low-level waste meeting LDRs. The NTS is retained as a feasible location for the final waste disposal.

2.8 Summary of Retained Technologies

The following list summarizes those primary and secondary treatment technologies that were retained through the screening process and incorporated into Section 3, "Development of Alternatives." Primary technologies represent the primary treatment process that would be applied to the tank contents. Secondary technologies are those that would be used in conjunction with the primary technology to treat secondary waste streams. (Note: In situ technologies are identified specifically. All others are assumed to be ex situ technologies.)

Primary technologies include:

- In situ vitrification
- Vitrification

- In situ chemical oxidation/reduction followed by stabilization
- Chemical oxidation/reduction with stabilization
- Thermal desorption.

Secondary technologies include:

- Amalgamation
- Encapsulation
- Incineration (off-Site only)
- Thermal oxidation
- Carbon absorption
- Filtration (off-gas)
- Evaporation.

Only remote tank-contents removal was retained, and the waste form disposal alternatives were all retained through the screening process, but they are not repeated or summarized here.

3. DEVELOPMENT OF ALTERNATIVES

From the list of potentially viable technologies identified in the previous section, and through continued evaluation of these as outlined in the Technology Evaluation Scope of Work (DOE-ID 2002a), three primary technologies ultimately were retained: (1) vitrification, (2) thermal desorption, and (3) chemical oxidation/reduction with stabilization. Specific alternatives associated with each technology, for which formal, detailed evaluations were conducted, are summarized below:

Vitrification:

- Alternative 1.a—In Situ Vitrification: In situ vitrification with disposal of the primary and the majority of the secondary waste streams at the ICDF

- Alternative 1.b—Ex Situ Vitrification: On-Site ex situ vitrification with disposal of the primary and the majority of the secondary waste streams at the ICDF.

Thermal Desorption:

- Alternative 2.a—Thermal Desorption On-Site/Off-Site: On-Site thermal desorption with disposal of residue at the ICDF and off-Site treatment and disposal of the secondary waste streams

- Alternative 2.b—Thermal Desorption On-Site: On-Site thermal desorption with disposal of residue at the ICDF and on-Site treatment and disposal of the secondary waste streams

- Alternative 2.c—Thermal Desorption Off-Site: On-Site thermal desorption with disposal of stabilized residue off-Site and off-Site treatment and disposal of the secondary waste streams.

Chemical Oxidation/Reduction with Stabilization:

- Alternative 3.a—In Situ Chemical Oxidation/Reduction followed by Stabilization: In situ chemical oxidation/reduction followed by stabilization with disposal of the primary and the majority of the secondary waste streams at the ICDF

- Alternative 3.b—Ex Situ Chemical Oxidation/Reduction followed by Stabilization: On-Site ex situ chemical oxidation/reduction followed by stabilization with disposal of the primary and the majority of the secondary waste streams at the ICDF.

The simplified PFDs presented in the following discussions are not intended to depict the detail of actual designs, and only those streams (shown in bold print in the figures) considered by the evaluation criteria are represented in the simplified mass balance tables. Significant effort was expended to identify and estimate the magnitude and approximate characterization of the expected waste streams to ensure that the ARARs were considered comprehensively and disposition pathways were identified for all waste. The summary waste disposition tables present an overview of the waste to be generated, the expected treatment requirements, and the planned disposition pathway. A greater level of detail is captured in the *Pre-Conceptual Designs of Various Alternatives for the V-Tanks, TSF-09/18 at Waste Area Group 1 Operable Unit 1-10* (INEEL 2002a), where the individual process streams are defined. Only limited information was obtained from potential technology vendors during this preconceptual design phase, so most of the design content was developed by technology experts at the INEEL. For each alternative

identified previously, it was assumed that a portion of the liquid (approximately 6,000 gal) from Tank V-3 was decanted, treated, stabilized, and disposed of at the ICDF before treatment of the remaining sludge and liquid in the tanks. Consequently, the material to be treated by each alternative consisted of a combination of liquid and sludge, as follows:

- Tank V-1—520 gal of sludge, plus 1,164 gal of liquid
- Tank V-2—458 gal of sludge, plus 1,138 gal of liquid
- Tank V-3—652 gal of sludge, plus 1,660 gal of liquid
- Tank V-9—250 gal of sludge, plus 70 gal of liquid.

As noted in Section 1.1, removal of 6,000 gal of liquid supernatant from Tank V-3 might not be completed. However, removal was assumed to ensure a common basis for performing the evaluation. In addition, it should be noted that the final design for the preferred alternative might differ from the preconceptual designs used in this evaluation.

3.1 Alternative 1.a—In Situ Vitrification with Disposal of the Primary and the Majority of the Secondary Waste Streams at the INEEL CERCLA Disposal Facility

Vitrification is a thermal treatment process used to convert various types of waste materials into chemically inert, stable glass and crystalline waste forms. The process involves Joule heating (heat produced by passing current through a resistive load—in this case, the targeted waste materials) to temperatures of 1,400–2,000°C, which is sufficient to melt the solid portion of the waste. Upon cooling, the vitrified waste form hardens into a durable glass and crystalline product with a leach resistance similar to that of basalt or obsidian.

During vitrification, nonvolatile inorganic contaminants and radionuclides in the waste are chemically incorporated into the glass and crystalline matrix, while hazardous organic contaminants are either destroyed in place (via pyrolysis) or removed and captured in the accompanying off-gas system (depending on their volatility). During the vitrification process, semivolatile inorganic contaminants (e.g., mercury and chlorides) also are removed from the waste and captured in the off-gas system.

Application to the V-Tanks involves deployment of an in situ vitrification system, complete with the associated off-gas cleanup system. A simplified PFD of in situ vitrification is shown in Figure 5, a summary mass balance showing the concentration of key streams is shown in Table 4, and waste types and volumes are summarized in Table 5.

In this process, graphite electrodes are installed in the soil around the tank to melt the waste in place. Then, sufficient current is passed (initially through a conductive starter path between electrodes), then through the melting soil, and, ultimately, through a molten mass incorporating soil, the tank, and the waste contents to form a relatively homogeneous vitrified mass. The type of melt conducted is referred to as a planar melt, in which the melt takes place at the level of the V-Tanks (10 to 20 ft below grade), eventually incorporating the tank and waste, but allowing vapors to emerge to the surface. Before beginning the melting process, soil (and possibly other absorbent fill material) is added to the tanks. Existing tank lines and portals are enlarged, as necessary, to direct and capture most of the off-gases above the ground, thereby precluding subsurface pressure buildup. A large hood is placed over the area to

capture the off-gases, which are treated through various wet (or dry) scrubber systems, filters, and a thermal oxidizer (TO) before being discharged. Granular-activated carbon and sulfur-impregnated granular activated carbon filters are used to remove organics and mercury, respectively, from the off-gases. The off-gas is assumed to be treated to meet MACT requirements. Secondary waste scrubber solutions are generated and must be treated and disposed of at the ICDF.

For all identified technologies, current plans call for clean closure of the tank system. For in situ vitrification, the resulting vitrified mass will be sized, removed, and disposed of at the ICDF. Surrounding soil will be sampled and disposed of at the ICDF, as required. Clean soil will be used to backfill the area of contamination. The selected vendor will establish the exact number of melts, but could range from one melt, if all of the sludge is first consolidated into one tank, to four melts, if each tank is treated separately. For this preconceptual design, it was assumed that one melt of the consolidated waste in one tank will be conducted. Although other waste material (e.g., piping) potentially could be incorporated into the melt. This was not factored into the design, but was considered during the evaluation process.

Another possible pretreatment option for the proposed in situ vitrification process involves decanting additional liquid (more than the aforementioned 6,000 gal) from the V-Tanks before initiating vitrification. By removing as much liquid as possible from the melt before in situ vitrification processing, the overall in situ vitrification process is made more efficient by eliminating the need to evaporate/boil off the water before melting the tank contents. In addition, removing excess free liquid from the tanks makes the overall in situ vitrification process more implementable. Therefore, in the preconceptual design, an additional decanting step to remove excess free liquid has been included before transferring the tank contents into one tank. The decanted liquid is processed with activated carbon to remove organic contaminants, and the liquid is stabilized for disposal at the ICDF. However, this option is not a prerequisite for planar in situ vitrification processing.

For purposes of estimating the mass balance around the in situ vitrification process, characterization data from other in situ vitrification applications were extrapolated as a basis for assuming that water and VOCs are vented from the waste during the initial heating produced by melting the soil around the tanks. These vapors are caught in the off-gas system liquid condensate or adsorbed onto activated carbon. Semivolatile organic compounds are pyrolized and destroyed in the melting process. Cadmium, chlorides, and mercury are vaporized from the melt and captured in the condensate, the HEPA filters, or in sulfur-impregnated carbon. In addition, trace amounts of radionuclides are partitioned between the melt, the condensate, and the HEPA filters. Only the carbon beds are disposed of off-Site; all other materials are disposed of at the ICDF.

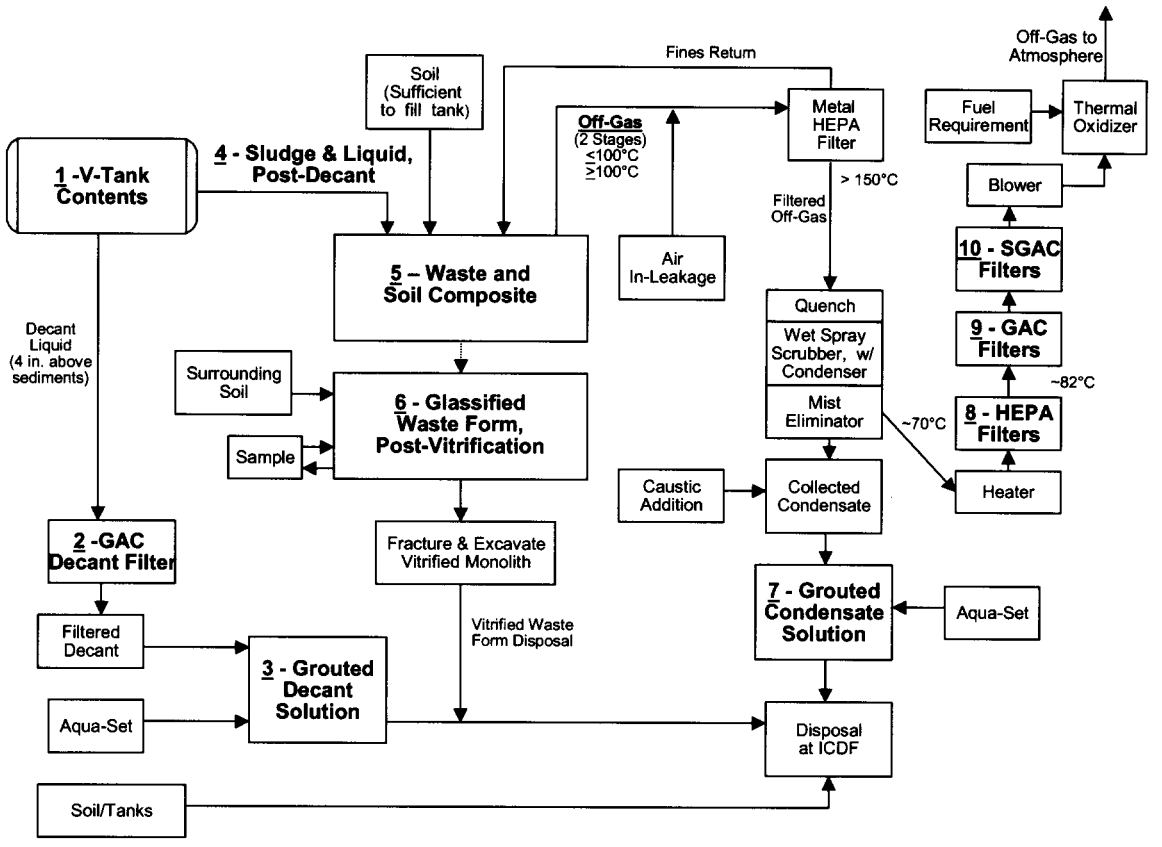


Figure 5. Alternative 1.a. process flow diagram for in situ vitrification.

Table 4. Summary mass balance for in situ vitrification.

Stream Name	V-Tank Contents	GAC Decant Filter	Grouted Decant Solution	Sludge and Liquid, Post-Decant	Decanted Sludge and Added Soil, Pre-Vitrification	Glassified Waste Form, Post-Vitrification	Grouted Condensate Solution	HEPA Filters	GAC Filter	SGAC Filter
Stream Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Volume (L)	2.24E+04	2.06E+01	1.47E+04	1.03E+04	3.79E+04	1.64E+05	3.41E+04	4.53E+02	1.99E+03	1.99E+03
Mass (kg)	2.26E+04	8.25E+00	1.69E+04	1.06E+04	6.32E+04	4.50E+05	3.91E+04	1.51E+01	7.94E+02	7.94E+02
Component										
Inorganics										
Cd (mg/kg)	2.02E+01	0	3.09E-02	4.32E+01	7.22E+00	0	7.28E-04	1.14E+00	0	0
Chlorides (mg/kg)	1.36E+02	0	9.42E+01	1.42E+02	2.37E+01	0	4.80E+01	0	0	0
Cr (mg/kg)	5.96E+02	0	9.82E-02	1.28E+03	2.72E+02	1.05E+02	0	0	0	0
Hg (mg/kg)	2.59E+02	Trace	7.99E-02	5.55E+02	9.27E+01	0	Trace	Trace	Trace	7.37E+03
Pb (mg/kg)	2.82E+02	0	1.82E-01	6.03E+02	1.01E+02	1.41E+01	Trace	Trace	0	0
VOCs										
PCE (mg/kg)	2.37E+02	4.27E+02	0	5.07E+02	8.47E+01	0	0	0	6.74E+03	Trace
TCA (mg/kg)	1.05E+02	1.22E+03	0	2.23E+02	3.72E+01	0	0	0	2.96E+03	Trace
TCE (mg/kg)	8.54E+02	8.97E+03	0	1.82E+03	3.05E+02	0	0	0	2.42E+04	Trace
SVOCs										
BEHP (mg/kg)	9.10E+02	1.53E+02	0	1.95E+03	3.26E+02	0	0	0	Trace	Trace
Araclor-1260 (mg/kg)	3.59E+01	1.45E+02	0	7.68E+01	1.28E+01	0	0	0	Trace	Trace
Radionuclides										
Cs-137 (nCi/g)	1.98E+03	0	4.13E+00	4.23E+03	7.06E+02	9.91E+01	3.42E-05	Trace	0	0
Sr-90 (nCi/g)	3.68E+03	0	7.74E+00	7.87E+03	1.32E+03	1.85E+02	2.13E-05	Trace	0	0
Transuranic (nCi/g)	8.57E+00	0	3.03E-03	1.84E+01	3.07E+00	4.30E-01	4.96E-08	Trace	0	0
Other										
Total Carbon (mg/kg)	2.53E+04	8.90E+04	0	5.42E+04	2.24E+04	0	0	0		Trace

BEHP = bis(2-ethylhexyl)phthalate
GAC = granular-activated carbon
HEPA = high-efficiency particulate air
PCE = tetrachloroethylene
SGAC = sulfur-impregnated granular-activated carbon
SVOC = semivolatile organic compound
TCA = trichloroethane
TCE = trichloroethylene
VOC = volatile organic compound

Table 5. Summary of waste types, volumes, expected treatments, and expected disposition for in situ vitrification.

Generated Waste Type	Volume	Expected Treatment	Expected Disposition
PRIMARY WASTE	**2,250 m^3 TOTAL**		
Grouted decant solution (Item 3 in PFD)	12 m^3 unstabilized, 14.8 m^3 stabilized	None—complete	ICDF (71 55-gal drums)
Glassified waste form (Item 6 in PFD)	165 m^3 (includes 0.95 m^3 of metal, 0.31 m^3 of phosphate, and 164 m^3 of vitrified waste form)	Fractured vitrified waste form in place, then excavate. Phosphate material will be packaged in two 55-gal drums.	ICDF, without packaging, for vitrified waste form and metal debris ICDF (two 55-gal drums) for phosphate material
Contaminated soil/tank area of contamination	2,070 m^3 (includes 2,068 m^3 of soil, 0.61 m^3 of tank shells, and 1.6 m^3 of piping)	Excavated (no treatment)	ICDF (without packaging)
SECONDARY WASTE	**123 m^3 TOTAL**		
GAC decant filter (Item 2 in PFD)	0.33 m^3	Thermal	Permafix/Envirocare
Grouted condensate solution (Item 7 in PFD)	27.9 m^3 unstabilized, 34.2 m^3 stabilized	None—complete	ICDF (157 55-gallon drums, plus the filled Tank V-9 shell)
Spent HEPA filters (Item 8 in PFDs)	0.45 m^3	Macroencapsulation for disposal	ICDF (four HEPA filters)
GAC filters (Item 9 in PFD)	2.0 m^3	Thermal	Permafix/Envirocare
SGAC filter (Item 10 in PFD)	2.0 m^3	None—complete	ICDF
Used PPE, consumable materials, nonrecoverable equipment	83.9 m^3	Macroencapsulation for disposal (as needed)	ICDF (Assume 12 10-yd^3 waste boxes)

GAC = granular-activated carbon
HEPA = high-efficiency particulate air
ICDF = INEEL CERCLA Disposal Facility
PFD = process flow diagram
PPE = personal protective equipment
SGAC = sulfur-impregnated granular-activated carbon

3.2 Alternative 1.b—On-Site Ex Situ Vitrification with Disposal of the Primary and the Majority of the Secondary Waste Streams at the INEEL CERCLA Disposal Facility

In the ex situ vitrification alternative, the tank contents are transferred into a nearby aboveground vitrification unit. The vitrification unit is preinsulated to preclude melting the container during ex situ vitrification processing. Then, soil from the area is added concurrently with the tank contents to provide the proper mix. A simplified PFD of ex situ vitrification is shown in Figure 6, a summary mass balance showing the concentration of key streams is shown in Table 6, and waste types and volumes are summarized in Table 7.

Graphite electrodes are used, as described in the in situ vitrification description, to vitrify the waste. However, in this application, all of the melting occurs inside the prefabricated vitrification unit, and the V-Tanks are not incorporated. The process includes an off-gas cleanup system comparable to the one required for in situ vitrification, and it produces comparable waste streams for disposal. The solidified mass and the prefabricated container(s) would be directly disposed of at the ICDF. As with the in situ vitrification alternative, additional decanting of the V-Tank supernatant is proposed as a pretreatment step to enhance melter efficiency and improve ex situ vitrification process implementability. However, the decanting process should not be considered a prerequisite.

To the extent possible, other waste (such as piping and soil) is incorporated into each melt. Then, the tanks and other contaminated soil are removed and disposed of at the ICDF. Finally, the area of contamination is backfilled and clean-closed.

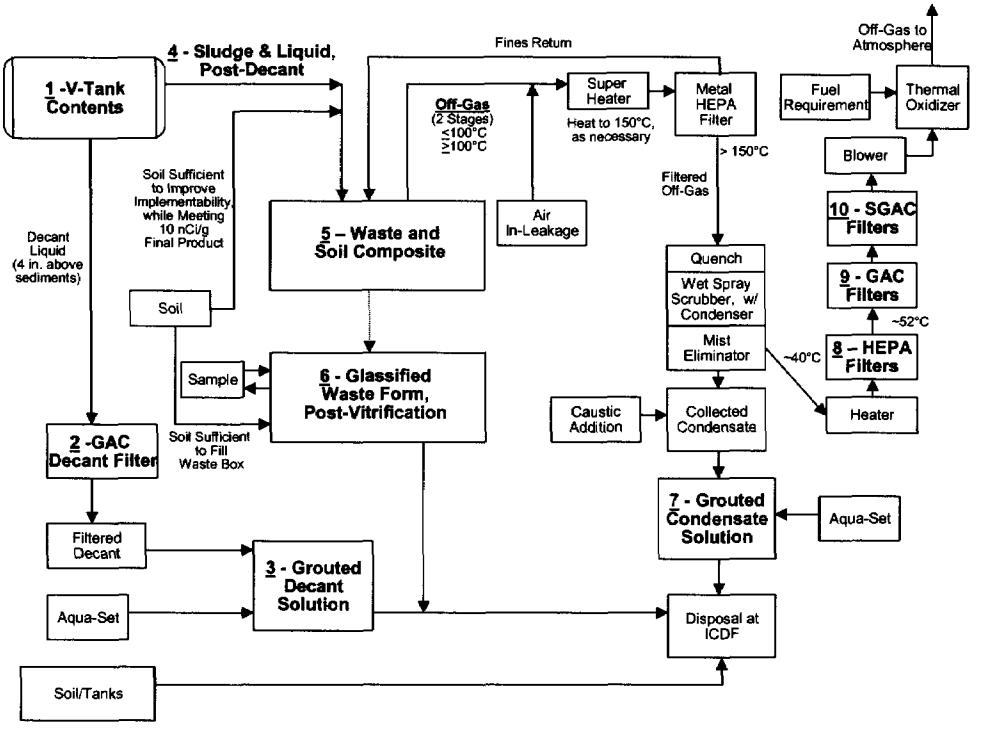


Figure 6. Alternative 1.b process flow diagram for ex situ vitrification.

Table 6. Summary mass balance for ex situ vitrification.

Stream Name	V-Tank Contents	GAC Decant Filter	Grouted Decant Solution	Sludge and Liquid Post-Decant	Decanted Sludge and Added Soil, Pre-Vitrification	Glassified Waste Form, Post-Vitrification	Grouted Condensate Solution	HEPA Filters	GAC Filter	SGAC Filter
Stream Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Volume (L)	2.24E+04	2.06E+01	1.47E+04	1.03E+04	3.23E+04	1.17E+04	6.99E+03	4.53E+02	1.82E+03	1.82E+03
Mass (kg)	2.26E+04	8.25E+00	1.69E+04	1.06E+04	5.04E+04	3.15E+04	8.01E+03	1.51E+01	7.27E+02	7.27E+02
Component										
Inorganics										
Cd (mg/kg)	1.36E+02	0	3.09E-02	4.32E+01	9.06E+00	0	5.68E-03	1.12E-02	0	0
Chlorides (mg/kg)	1.65E+02	0	9.42E+01	1.42E+02	2.97E+01	0	2.57E+02	0	0	0
Cr (mg/kg)	5.96E+02	0	9.82E-02	1.28E+03	3.23E+02	5.18E+02	0	0	0	0
Hg (mg/kg)	2.59E+02	Trace	7.99E-02	5.55E+02	1.16E+02	0	Trace	Trace	Trace	8.05E+03
Pb (mg/kg)	2.82E+02	0	1.82E-01	6.03E+02	1.26E+02	2.02E+02	Trace	Trace	0	0
VOCs										
PCE (mg/kg)	2.37E+02	4.27E+02	0	5.07E+02	1.06E+02	0	0	0	7.36E+03	Trace
TCA (mg/kg)	1.05E+02	1.22E+03	0	2.23E+02	4.67E+01	0	0	0	3.23E+03	Trace
TCE (mg/kg)	8.54E+02	8.97E+03	0	1.82E+03	3.82E+02	0	0	0	2.65E+04	Trace
SVOCs										
BEHP (mg/kg)	9.10E+02	1.53E+02	0	1.95E+03	4.08E+02	0	0	0	Trace	Trace
Araclor-1260 (mg/kg)	3.59E+01	1.45E+02	0	7.68E+01	1.61E+01	0	0	0	Trace	Trace
Radionuclides										
Cs-137 (nCi/g)	1.98E+03	0	4.13E+00	4.23E+03	8.86E+02	1.42E+03	1.67E-04	Trace	0	0
Sr-90 (nCi/g)	3.68E+03	0	7.74E+00	7.87E+03	1.65E+03	2.64E+03	1.04E-04	Trace	0	0
Transuranic (nCi/g)	8.57E+00	0	3.03E-03	1.84E+01	3.85E+00	6.16E+00	2.42E-07	Trace	0	0
Other										
Total Carbon (mg/kg)	2.53E+04	8.90E+04	0	5.42E+04	2.41E+04	0	0	0		Trace

BEHP = bis(2-ethylhexyl)phthalate
GAC = granular-activated carbon
HEPA = high-efficiency particulate air
PCE = tetrachloroethylene
SGAC = sulfur-impregnated granular-activated carbon
SVOC = semivolatile organic compound
TCA = trichloroethane
TCE = trichloroethylene
VOC = volatile organic compound

Table 7. Summary table of generated waste, volumes, and expected disposition for ex situ vitrification.

Generated Waste Type	Volume	Expected Treatment	Expected Disposition
PRIMARY WASTE	**2,427 m^3 TOTAL**		
Grouted decant solution (Item 3 in PFD)	12 m^3 unstabilized, 14.8 m^3 stabilized	None—complete	ICDF (71 55-gal drums)
Roll-off boxes, containing glassified waste form (Item 6 in PFD)	Total volume of 68.9 m^3, (includes 36 m^3 of refractory material, 11.7 m^3 of vitrified waste form, and 21.2 m^3 of contaminated soil)	No further treatment is required. Soil is added to fill the void left from subsidence, during the batch ex situ vitrification process.	ICDF (Six roll-off boxes)
Contaminated soil/tank area of contamination	2,343 m^3 (includes 2,340 m^3 of soil, 1.5 m^3 of tank shell, and 1.6 m^3 of miscellaneous piping)	Excavated (no treatment)	ICDF (without packaging)
SECONDARY WASTE	**88 m^3 TOTAL**		
GAC decant filters (Item 2 in PFD)	0.33 m^3	Thermal	Permafix/Envirocare
Grouted condensate solution (Item 7 in PFD)	5.7 m^3 unstabilized, 7.1 m^3 stabilized	None—complete	ICDF (27 55-gal drums, plus the filled Tank V-9 shell)
Spent HEPA filters (Item 8 in PFD)	0.45 m^3	Macroencapsulation for disposal	ICDF (four HEPA filters)
GAC filters (Item 9 in PFD)	1.8 m^3	Thermal	Permafix/Envirocare
SGAC filters (Item 10 in PFD)	1.8 m^3	None—complete	ICDF
Used PPE, consumable materials, nonrecoverable equipment	76.4 m^3	Macroencapsulation for disposal (as needed)	ICDF (Assume 12 10-yd^3 waste boxes)

GAC = granular-activated carbon
HEPA = high-efficiency particulate air
ICDF = INEEL CERCLA Disposal Facility
PFD = process flow diagram
PPE = personal protective equipment
SGAC = sulfur-impregnated granular-activated carbon

3.3 Alternative 2.a—On-Site Thermal Desorption with Disposal of Residue at the INEEL CERCLA Disposal Facility and Off-Site Treatment and Disposal of the Secondary Waste Streams

Typically, thermal desorption is used as a separation process, often as the first step in a treatment train. Thermal desorption removes water, volatile organics, and volatile metals (such as mercury) from solids and liquids by raising the temperature of the waste to a level sufficient to volatilize contaminants and transfer them to the off-gas stream. After the various hazardous constituents are separated into discrete waste streams, these relatively homogenous waste types can be treated separately.

Various thermal desorption technologies employ differing combinations of temperature, residence times, feed mixing, and vacuum to heat the material and transfer the contaminants to the off-gas stream. Most commercial applications have been performed on contaminated soil. Several classes of thermal desorber units have emerged, including indirect- and direct-heated units, units operated at atmospheric conditions, and units operated under vacuum. The thermal desorption system proposed for treatment of V-Tanks liquid and sludge waste will be a vacuum thermal desorption unit (an indirectly heated rotary kiln, operated under vacuum). However, the vacuum need not be applied until after the higher-volume, lower-temperature VOCs (and water) have been desorbed.

Using this alternative, V-Tank contents are transferred to the thermal desorption unit and combined with soil from the area of contamination. Unlike the vitrification process, additional liquid (in excess of the 6,000 gal from Tank V-3) is not decanted first. A simplified PFD of thermal desorption on-Site/off-Site, which combines on-Site disposal of thermal desorption waste with off-Site treatment and disposal of off-gas residuals, is shown in Figure 7. A summary mass balance showing the concentration of key streams is shown in Table 8, and waste types and volumes are summarized in Table 9.

Initially, liquid and sludge waste is removed from each V-Tank using a fluidic jet-removal system and pumped directly to the thermal desorption unit, where it is combined with soil sufficient to adjust moisture levels to within the normal operating range of the thermal desorption unit. Once the soil/waste has been received, the thermal desorption unit is set in rotation and heated for 1 hour at 95°C at 620 mm Hg (low-temperature mode of operation). During this period, 100% of the water and low-temperature organic contaminants and about 20% of the mercury is desorbed. Following low-temperature operations, a vacuum (40 mm Hg) is established on the rotating vessel, and the unit is heated for 2 hours at up to 400°C (high-temperature mode of operation). It is during this period that 100% of the SVOCs and the remaining mercury is desorbed.

Not unlike the vitrification process, a relatively sophisticated off-gas system is used to collect and treat the off-gas. Since the process operates at lower temperatures, cesium levels in the off-gas system are reduced. No on-Site organic destruction technology is used in this alternative, so the off-gas treatment train is not designed to be compliant with MACT requirements. In addition, during high-temperature operations, the condenser and mist eliminator are bypassed to maintain the off-gas temperature (after nitrogen dilution) and avoid condensation before the GAC/SGAC filters. Partitioning of contaminants is similar to the vitrification process in that VOCs are captured on activated carbon and mercury is adsorbed on sulfur-impregnated carbon. However, cadmium is not volatilized due to the lower operating temperature. The SVOCs are captured on the activated carbon. These slightly radioactive off-gas waste streams (condensate and filters) will be containerized and shipped off-Site for treatment and disposal. Details on the contaminant partitioning can be found in Table 8.

After high-temperature operation, the waste containing most of the heavy metals and radionuclides is cooled and transferred to the hopper vessel for containerization. Based on the material balances, this material should not require stabilization and can be containerized and disposed of at the ICDF. The tanks and remaining soil also would be disposed of at the ICDF.

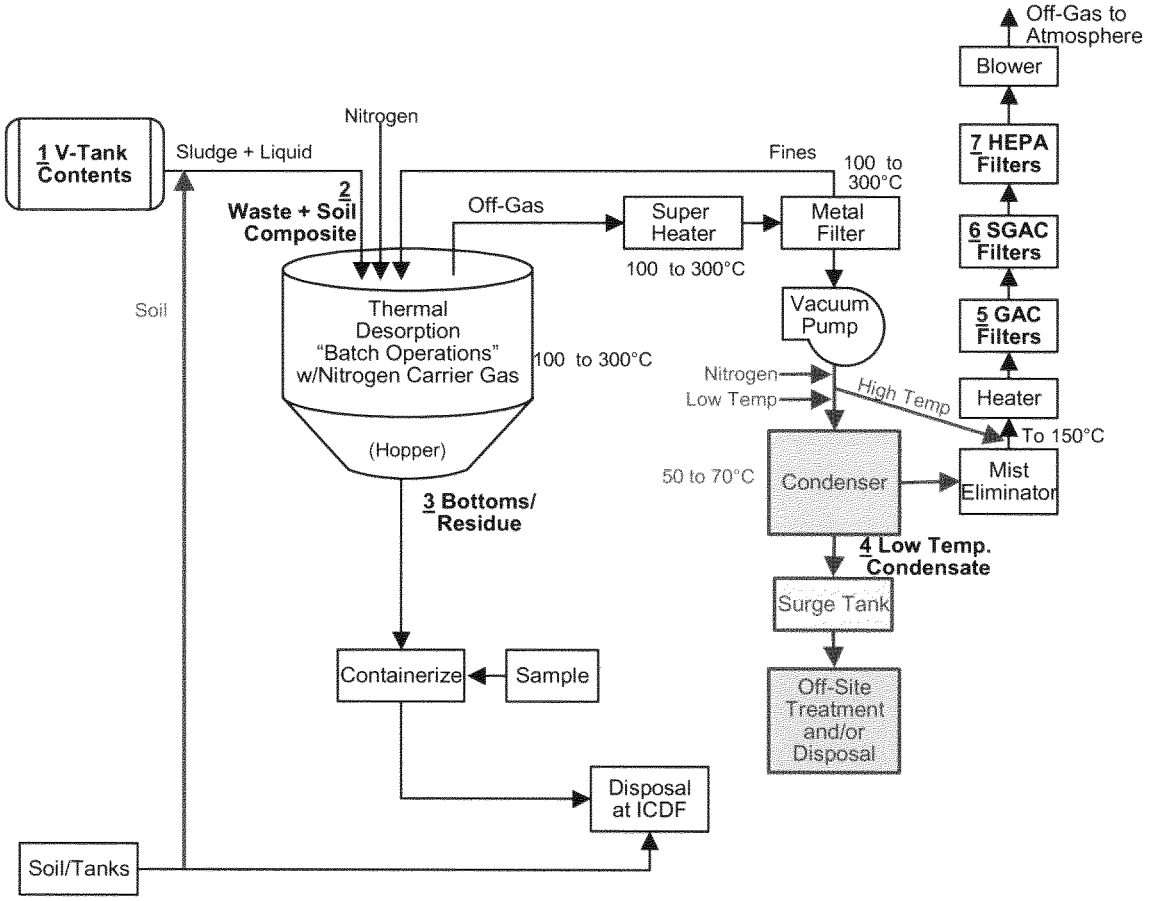


Figure 7. Alternative 2.a process flow diagram for thermal desorption on-Site/off-Site.

Table 8. Summary mass balance for thermal desorption on-Site/off-Site.

Stream Name	V-Tank Contents	Waste + Soil Composite	Bottoms Residue	Low-Temperature Condensate	GAC Filters	SGAC Filters	HEPA Filters
Stream Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Volume (L)	2.24E+04	1.82E+05		5.03E+04	1.84E+4	9.91E+01	
Mass (kg)	2.26E+04	3.04E+05	2.43E+05	5.03E+04	7.36E+3	3.96E+01	
Component							
Inorganics							
Cd (mg/kg)	2.02E+01	1.49E+00	1.86E+00				
Chlorides (ppm)	1.36E+02	1.67E+01	2.06E-03		1.65E+2		
Cr (mg/kg)	5.96E+02	4.44E+01	5.54E+01				
Hg (mg/kg)	2.59E+02	1.93E+01	2.35E-02	1.50E+01		1.29E+4	
Pb (mg/kg)	2.82E+02	2.00E+01	2.62E+01				
VOC							
PCE (ppm)	2.37E+02	2.91E+01	0.00E+00	2.14E+01	2.30E+2		
TCA (ppm)	1.05E+02	1.29E+01	0.00E+00	9.42E+00	1.02E+2		
TCE (ppm)	8.54E+02	1.05E+02	0.00E+00	7.71E+01	8.28E+2		
SVOC							
BEHP (ppm)	9.10E+02	1.12E+02	8.81E-02		1.11E+3		
PCBs (ppm)	3.59E+01	4.42E+00	3.44E-03		4.36E+1		
Radionuclide							
Cs-137 (nCi/g)	1.98E+03	1.47E+02	1.84E+02	Trace	Trace		Trace
Sr-90 (nCi/g)	3.68E+03	2.74E+02	3.41E+02	Trace	Trace		Trace
Transuranic (nCi/g)	8.57E+00	6.37E-01	7.97E-01	Trace	Trace		Trace
Other							
Total Organic Carbon (ppm)	2.53E+04	3.11E+03	0.00E+00		3.08E+4		

BEHP = bis(2-ethylhexyl)phthalate
GAC = granular-activated carbon
HEPA = high-efficiency particulate air
PCE = tetrachloroethylene
SGAC = sulfur-impregnated granular-activated carbon
SVOC = semivolatile organic compound
TCA = trichloroethane
TCE = trichloroethylene
VOC = volatile organic compound

Table 9. Summary of generated waste, volumes, and expected disposition for thermal desorption on-Site/off-Site.

Generated Waste Type	Volume	Expected Treatment	Expected Disposition
PRIMARY WASTE	**2,407 m^3**		
Bottoms/residue (Item 3 in PFD)	203 m^3	None—Calculations indicate that stabilization is not required.	ICDF
Contaminated soil/tanks from V-Tank area of contamination	2,204 m^3	Excavated (no treatment)	ICDF
SECONDARY WASTE	**133 m^3**		
Low-temperature condensate (Item 4 in PFD)	48.3 m^3	Thermal and stabilization for disposal	Permafix/Envirocare
GAC filters (Item 5 in PFD)	24.9 m^3	Thermal	Permafix/Envirocare
SGAC filters (Item 6 in PFD)	1.1 m^3	None—complete	Envirocare
HEPA filters (Item 7 in PFD)	0.7 m^3	Macroencapsulation for disposal	Envirocare
Used PPE, consumable materials, nonrecoverable equipment	58.1 m^3	Macroencapsulation for disposal (as needed)	ICDF (or Envirocare)

GAC = granular-activated carbon
HEPA = high-efficiency particulate air
ICDF = INEEL CERCLA Disposal Facility
PFD = process flow diagram
PPE = personal protective equipment
SGAC = sulfur-impregnated granular-activated carbon

3.4 Alternative 2.b—On-Site Thermal Desorption with Disposal of Residue at the INEEL CERCLA Disposal Facility and On-Site Treatment and Disposal of the Secondary Waste Streams

This alternative employs a thermal desorption system identical to the previous alternative, but the off-gas system is modified to include organic destruction, which facilitates treatment of all secondary waste on-Site. This process uses a TO for destroying the organics, versus off-Site treatment and disposal; thus, the off-gas system is designed to MACT requirements. A simplified PFD of thermal desorption on-Site is shown in Figure 8, a summary mass balance showing the concentration of key streams is shown in Table 10, and waste types and volumes are summarized in Table 11.

Rather than collecting the organic constituents on carbon beds, they are destroyed by the thermal oxidizer as they are desorbed. This allows the wet scrub/quench system to be operated during both low- and high-temperature desorption. This causes more condensation of volatilized constituents and reduces the requirement for activated carbon. A somewhat different partitioning of volatile species is produced, resulting in more chlorides and mercury entering the scrub system. Then, the scrub/condensate solutions are stabilized. All waste products from this alternative can be disposed of at the ICDF.

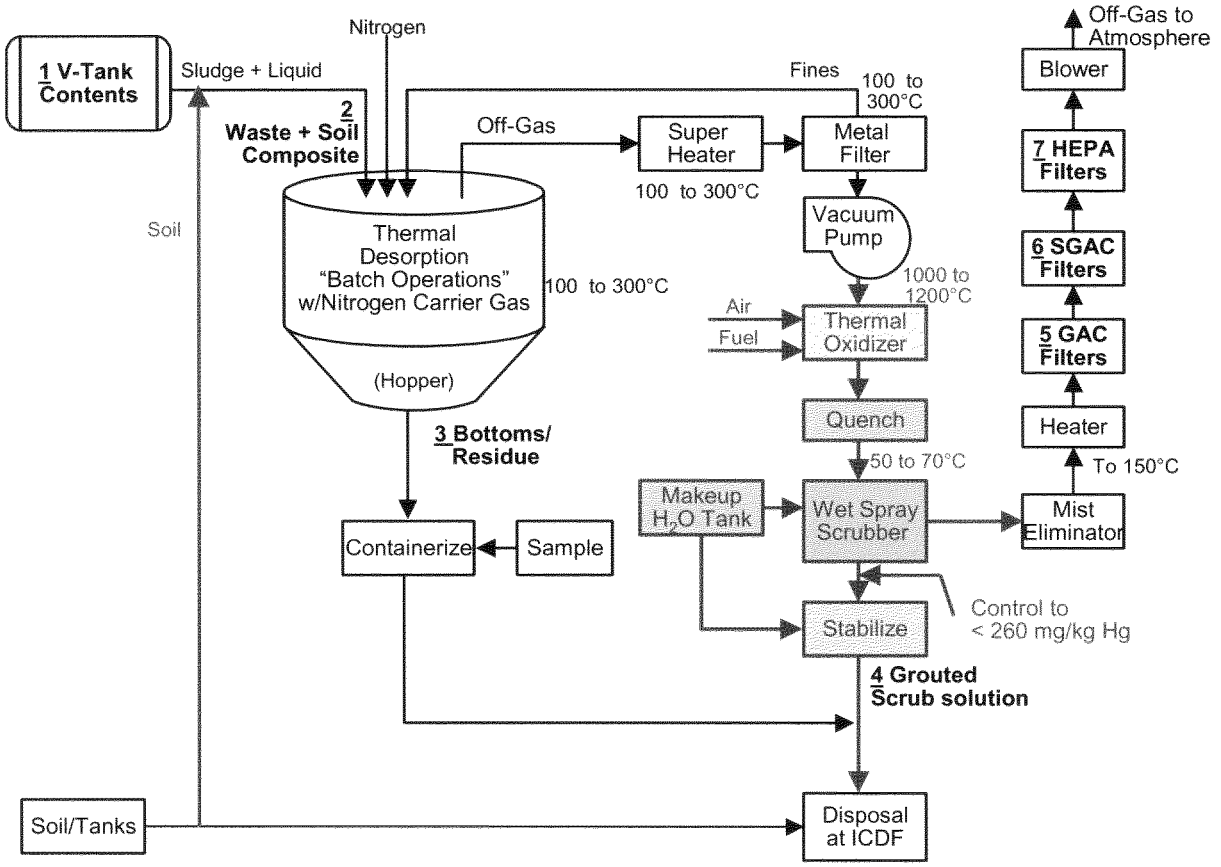


Figure 8. Alternative 2.b process flow diagram for thermal desorption on-Site.

Table 10. Summary mass balance for thermal desorption on-Site.

Stream Name	V-Tank Contents	Waste + Soil Composite	Bottoms/ Residue	Grouted Scrub Solutions	GAC Filters	SGAC Filters	HEPA Filters
Stream Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Volume (L)	2.24E+04	1.82E+05	2.43E+05	1.41E+4	2.49E+4	5.89E+3	
Mass (kg)	2.26E+04	3.04E+05	2.43E+05	1.41E+4	9.97E+3	2.36E+3	
Component							
Inorganics							
Cd (mg/kg)	2.02E+01	1.49E+00	1.86E+00				
Chlorides (ppmv)	1.36E+02	1.67E+01	2.06E-03	2.16E+2			
Cr (mg/kg)	5.96E+02	4.44E+01	5.54E+01				
Hg (mg/kg)	2.59E+02	1.93E+01	2.35E-02	1.50E+2	1.11E+2	1.11E+3	
Pb (mg/kg)	2.82E+02	2.00E+01	2.62E+01				
VOC							
PCE (ppmv)	2.37E+02	2.91E+01	0.00E+00				
TCA (ppmv)	1.05E+02	1.29E+01	0.00E+00				
TCE (ppmv)	8.54E+02	1.05E+02	0.00E+00				
SVOC							
BEHP (ppmv)	9.10E+02	1.12E+02	8.81E-02				
PCBs (ppmv)	3.59E+01	4.42E+00	3.44E-03				
SVOCs (ppmv)	2.78E+01	3.42E+00	0.00E+00				
Radionuclide							
Cs-137 (nCi/g)	1.98E+03	1.49E+02	1.84E+02		Trace	Trace	Trace
Sr-90 (nCi/g)	3.68E+03	2.74E+02	3.41E+02		Trace	Trace	Trace
Transuranic (nCi/g)	8.57E+00	6.37E-01	7.97E-01		Trace	Trace	Trace
Other							
Total Organic Carbon (ppmv)	2.53E+04	3.11E+03	0.00E+00				

BEHP = bis(2-ethylhexyl)phthalate
GAC = granular-activated carbon
HEPA = high-efficiency particulate air
PCE = tetrachloroethylene
SGAC = sulfur-impregnated granular-activated carbon
SVOC = semivolatile organic compound
TCA = trichloroethane
TCE = trichloroethylene
VOC = volatile organic compound

Table 11. Summary table of generated waste, volumes, and expected disposition for thermal desorption on-Site.

Generated Waste Type	Volume	Expected Treatment	Expected Disposition
PRIMARY WASTE	**2,407 m^3**		
Bottoms/residue (Item 3 in PFD)	203 m^3	None—Calculations indicate that stabilization is not required.	ICDF
Contaminated soil/tanks from V-Tank area of contamination	2,204 m^3	Excavated (no treatment)	ICDF
SECONDARY WASTE	**110 m^3**		
Grouted scrub solution (Item 4 in PFD)	16.5 m^3	None—complete	ICDF
GAC filters (Item 5 in PFD)	5.7 m^3	None—complete	ICDF
SGAC filters (Item 6 in PFD)	5.7 m^3	None—complete	ICDF
HEPA filters (Item 7 in PFD)	0.7 m^3	Macroencapsulation for disposal	ICDF
Used PPE, consumable materials, nonrecoverable equipment	81.7 m^3	Macroencapsulation for disposal (as needed)	ICDF

GAC = granular-activated carbon
HEPA = high-efficiency particulate air
ICDF = INEEL CERCLA Disposal Facility
PFD = process flow diagram
PPE = personal protective equipment
SGAC = sulfur-impregnated granular-activated carbon

3.5 Alternative 2.c—On-Site Thermal Desorption with Disposal of Stabilized Residue Off-Site and Off-Site Treatment and Disposal of the Secondary Waste Streams

This alternative eliminates the use of soil in the desorber, allowing a smaller unit to be used, and it results in waste products suitable for off-Site treatment and disposal (NTS, Hanford, etc.). A simplified PFD of thermal desorption off-Site is shown in Figure 9, a summary mass balance showing the concentration of key streams is shown in Table 12, and waste types and volumes are summarized in Table 13.

As in the previous thermal desorption alternatives, liquid and sludge waste is removed from each V-Tank using a fluidic jet-removal system and pumped directly to the thermal desorption unit (4 ft in diameter and 8.5 ft long), but no carrier soil is employed. This minimizes the residual waste volume, but also maximizes the radiological concentration. The staged desorption process is identical to that described in the first thermal desorption alternative (2.a) in that it uses an off-gas system without on-Site organic destruction and does not require design to MACT requirements. Partitioning of the desorbed constituents amongst the secondary waste streams is, therefore, similar to the first thermal desorption alternative, although the volume is reduced due to elimination of the soil addition. Details of this distribution can be found in Table 12.

After high-temperature operation, the inorganic waste containing most of the heavy metals and radionuclides is cooled and transferred to the hopper vessel for containerization. After containerization, the waste is placed in interim storage and later shipped to an off-Site disposal facility, such as the WIPP, NTS, or Hanford. In the event transuranic levels meet WIPP criteria, the residue will be stored without stabilization. If the transuranic levels are less than the WIPP criteria (>100 nCi/g, which is expected based on the material balance), the residue will be stabilized to meet LDRs and comply with NTS and Hanford waste acceptance criteria and radiological licenses. Currently, these sites are accepting only mixed waste from within their respective states and are pursuing the capability to receive out-of-state waste. Since they are not currently authorized to accept V-Tank waste, it is assumed that the waste (inorganic bottoms/residue) will be placed in on-Site interim storage for approximately 2 years until authorization is granted.

The secondary off-gas waste streams are treated and disposed of at other facilities off-Site (as in the thermal desorption on-Site/off-Site alternative). The tanks and soil will be sent to the ICDF for disposal.

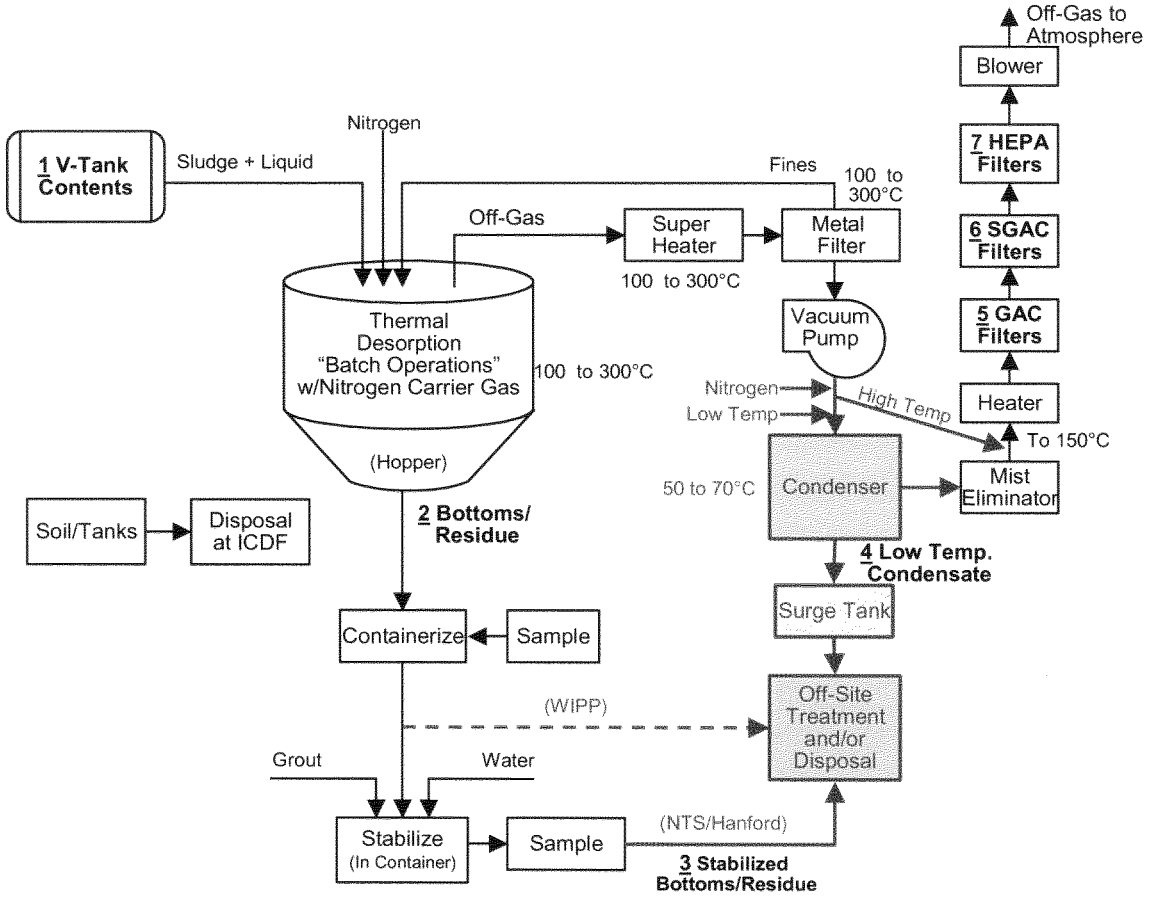


Figure 9. Alternative 2.c process flow diagram for thermal desorption off-Site.

Table 12. Summary mass balance for thermal desorption off-Site.

Stream Name	V-Tank Contents	Bottoms/ Residue	Stabilized Bottoms/ Residue	Low-Temperature Condensate	GAC Filters	SGAC Filters	HEPA Filters
Stream Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Volume (L)	2.24E+04	2.80E+03	5.0E+03	1.37E+04	1.84E+4	6.51E+02	
Mass (kg)	2.26E+04	2.80E+03	7.0E+03	1.37E+04	7.36E+3	2.60E+02	
Component							
Inorganics							
Cd (mg/kg)	2.02E+01	1.61E+02	6.46E+01				
Chlorides (ppmv)	1.36E+02	1.84E-01	1.05E-01		1.65E+2		
Cr (mg/kg)	5.96E+02	4.81E+03	1.92E+3				
Hg (mg/kg)	2.59E+02	1.68E+00	1.11E+00	5.14E+01		1.97E+4	
Pb (mg/kg)	2.82E+02	2.28E+03	9.10E+02				
VOC							
PCE (ppmv)	2.37E+02	0.00E+00	0.00E+00	7.94E+01	2.29E+2		
TCA (ppmv)	1.05E+02	0.00E+00	0.00E+00	3.47E+01	1.02E+2		
TCE (ppmv)	8.54E+02	0.00E+00	0.00E+00	2.84E+02	8.28E+2		
SVOC							
BEHP (ppmv)	9.10E+02	7.63E+00	4.4E+00		1.11E+3		
PCBs (ppmv)	3.59E+01	3.07E-01	1.75E-01		6.36E+1		
Radionuclide							
Cs-137 (nCi/g)	1.98E+03	1.60E+6	6.39E+3	Trace	Trace	Trace	Trace
Sr-90 (nCi/g)	3.68E+03	2.98E+04	1.19E+04	Trace	Trace	Trace	Trace
Transuranic (nCi/g)	8.57E+00	6.92E+01	2.77E+01	Trace	Trace	Trace	Trace
Other							
Total Organic Carbon (ppmv)	2.53E+04	0.00E+00	0.00E+00		3.08E+4		

BEHP = bis(2-ethylhexyl)phthalate
GAC = granular-activated carbon
HEPA = high-efficiency particulate air
PCE = tetrachloroethylene
SGAC = sulfur-impregnated granular-activated carbon
SVOC = semivolatile organic compound
TCA = trichloroethane
TCE = trichloroethylene
VOC = volatile organic compound

Table 13. Summary table of generated waste, volumes, and expected disposition for thermal desorption off-Site.

Generated Waste Type	Volume	Expected Treatment	Expected Disposition
PRIMARY WASTE	**2,397 m^3**		
Stabilized bottoms/residue (Item 3 in PFD)	2.4 m^3 unstabilized, 5 m^3 stabilized	None—complete	NTS, Hanford
Contaminated soil/tanks from V-Tank area of contamination	2,392 m^3	Excavated (no treatment)	ICDF
SECONDARY WASTE	**93 m^3**		
Low-temperature condensate (Item 4 in PFD)	13.1 m^3	Thermal and stabilization for disposal	Permafix/Envirocare
GAC filters (Item 5 in PFD)	24.9 m^3	Thermal	Permafix/Envirocare
SGAC filters (Item 6 in PFD)	1.1 m^3	None—complete	Envirocare
HEPA filters (Item 7 in PFD)	0.7 m^3	Macroencapsulation for disposal	Envirocare
Used PPE, consumable materials, nonrecoverable equipment	53.4 m^3	Macroencapsulation for disposal (as needed)	ICDF (or Envirocare)

GAC = granular-activated carbon
HEPA = high-efficiency particulate air
ICDF = INEEL CERCLA Disposal Facility
NTS = Nevada Test Site
PFD = process flow diagram
PPE = personal protective equipment

3.6 Alternative 3.a—In Situ Chemical Oxidation/Reduction and Stabilization with Disposal of the Primary and the Majority of the Secondary Waste Streams at the INEEL CERCLA Disposal Facility

The chemical oxidation and stabilization process proposed for treatment of V-Tank waste is a low-temperature process using an aqueous solution of sodium persulfate to convert organic solids and liquids to carbon dioxide, water, and halide salts at temperatures below 100°C. In situ CO/S is proposed as a batch process occurring in sequence in Tanks V-1, V-2, and V-3. The contents of Tank V-9 will be transferred to Tank V-2 before processing using a fluidic jet system, which also will facilitate mixing of the chemical oxidant throughout the process. A simplified PFD of IS-CO/S is shown in Figure 10, a summary mass balance showing the concentration of key streams is shown in Table 14, and waste types and volumes are summarized in Table 15.

To complete the preconceptual designs that provided the basis for the comparative analysis, it was necessary to assume a specific oxidant—in this case, sodium persulfate. However, other oxidants or reductants may be specified ultimately during the design phase.

The tank contents will be maintained at a controlled pH with sodium hydroxide and nitric acid. Acidic conditions are generally favored for oxidation, while basic solutions are favored for stabilization of halide-rich mixtures. Then, persulfate, in aqueous solution (29 w% solution), will be added in three successive aliquots. The first aliquot will be added while the solution is at ambient temperature (approximately 20°C) and will consist of a volume of persulfate solution equal to 20% of the initial volume of waste in each tank. Adding the first aliquot of persulfate before heating to 80°C will allow initiation of chemical oxidation/reduction on the VOCs. This will minimize the mass of VOCs that must be captured in the GAC bed. Adjusting the pH might be necessary during chemical oxidation to keep the oxidizing solution from becoming too acidic. Then, the solution will be held at 80°C, and the second and third aliquots of persulfate will be added to complete the reaction.

Upon completion of the final reaction step, the oxidized liquid waste will be sampled and analyzed for key contaminants (BEHP, etc.). If sufficient destruction and removal efficiencies (DREs) have not been achieved, then the mixture will be further reacted until compliance is achieved. Once adequate destruction efficiency is achieved, the pH will be checked and adjusted, as necessary, to facilitate stabilization to (1) stabilize the remaining inorganic contaminants, metals, and radionuclides, and (2) eliminate free liquid so the resulting solid can be sent to the ICDF for disposal. Adjusting the pH after chemical oxidation is necessary since groutability of the processed waste is optimized at, or near, the pH of the grout used in the solidification. The pH of most cementitious grouts is approximately pH 10–12. In-tank grouting will be accomplished using a multiport injection system (or equivalent). Sampling and analysis of grouted waste will be completed to verify compliance with regulatory standards (e.g., LDRs) before disposal. The tanks and surrounding soil would then be removed and disposed of at the ICDF.

The off-gas system is used to capture any water or contaminants (VOCs, mercury, etc.) evaporated during the exothermic oxidation step. The condensate is continuously recycled back to the tank to increase destruction of any VOCs. Any VOCs not condensed are captured on a GAC filter that will be treated and disposed of at an off-Site TSDF, since VOC concentrations are expected to exceed the ICDF's waste acceptance criteria. If there are residual mercury vapors, they are captured on a SGAC filter that can be disposed of at the ICDF, since it is expected to meet the ICDF's waste acceptance criteria.

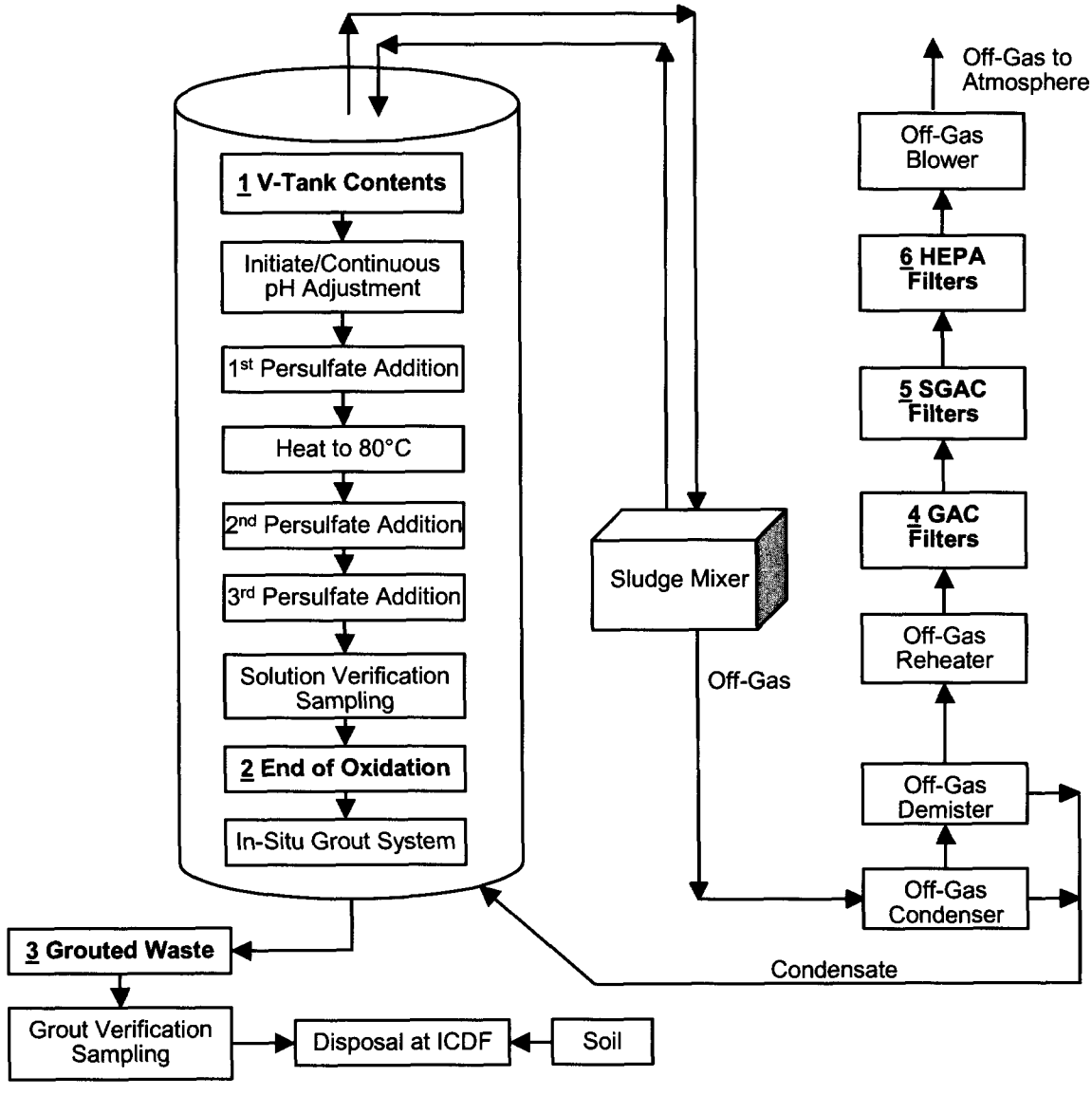


Figure 10. Alternative 3.a process flow diagram for in situ chemical oxidation/reduction followed by stabilization.

Table 14. Summary mass balance for in situ chemical oxidation/reduction followed by stabilization and ex situ chemical oxidation/reduction followed by stabilization.

Stream Name	V-Tank Contents	End of Oxidation	Grouted Waste	GAC Filter	SGAC Filter	HEPA Filter
Stream Number	**1**	**2**	**3**	**4**	**5**	**6**
Volume (L)	2.24E+04	3.15E+04	6.70E+04	4.16E+02	4.16E+02	3.00E+02
Mass (kg)	2.26E+04	3.29E+04	1.15E+05	1.67E+02	1.67E+02	1.0E+01
Component						
Inorganics						
Cd (mg/kg)	2.02E+01	1.39E+01	3.96E+00	0.00E+00	0.00E+00	0.00E+00
Chlorides (mg/kg)	1.36E+02	7.99E+02	2.28E+02	0.00E+00	0.00E+00	0.00E+00
Cr (mg/kg)	5.96E+02	4.09E+02	1.17E+02	0.00E+00	0.00E+00	0.00E+00
Pb (mg/kg)	2.82E+02	1.93E+02	5.53E+01	0.00E+00	0.00E+00	0.00E+00
Hg (mg/kg)	2.59E+02	1.78E+02	5.08E+01	0.00E+00	3.50E+01	0.00E+00
VOCs						
PCE (mg/kg)	2.37E+02	1.46E+00	4.18E-01	6.41E+01	0.00E+00	0.00E+00
TCA (mg/kg)	1.05E+02	7.20E-01	2.06E-01	2.84E+01	0.00E+00	0.00E+00
TCE (mg/kg)	8.54E+02	2.93E+00	8.37E-01	2.31E+02	0.00E+00	0.00E+00
SVOC						
BEHP (mg/kg)	9.10E+02	6.24E+01	1.78E+01	6.16E+01	0.00E+00	0.00E+00
PCBs (mg/kg)	3.59E+01	3.69E+00	1.06E+00	2.43E+00	0.00E+00	0.00E+00
Radionuclide						
Cs-137 (nCi/g)	1.98E+03	1.36E+03	3.88E+02	0.00E+00	0.00E+00	0.00E+00
Sr-90 (nCi/g)	3.68E+03	2.52E+03	7.21E+02	0.00E+00	0.00E+00	0.00E+00
Transuranic (nCi/g)	8.57E+00	5.88E+00	1.68E+00	0.00E+00	0.00E+00	0.00E+00
Other						
Total Organic Carbon (ppm)	2.53E+04	1.74E+02	4.96E+01	–	0.00E+00	0.00E+00

* Chlorides are reflective of dissolved free chloride ion in solution.
BEHP = bis(2-ethylhexyl)phthalate
GAC = granular-activated carbon
HEPA = high-efficiency particulate air
PCE = tetrachloroethylene
SGAC = sulfur-impregnated granular-activated carbon
SVOC = semivolatile organic compound
TCA = trichloroethane
TCE = trichloroethylene
VOC = volatile organic compound

Table 15. Summary table of generated waste, volumes, and expected disposition for in situ chemical oxidation/reduction followed by stabilization.

Generated Waste Type	Volume	Expected Treatment	Expected Disposition
PRIMARY WASTE	**2,462 m^3**		
Grouted waste (in tank) (Item 3 in PFD)	75 m^3	None—complete	ICDF
Contaminated soil/tanks from V-Tank area of contamination	2,387 m^3	Excavated (no treatment)	ICDF
SECONDARY WASTE	**44 m^3**		
GAC filters (Item 4 in PFD)	1 m^3	Thermal	Permafix/Envirocare
SGAC filters (Item 5 in PFD)	1 m^3	None—complete	ICDF
HEPA filters (Item 6 in PFD)	0.3 m^3	Macroencapsulation for disposal	ICDF
Used PPE, consumable materials, nonrecoverable equipment	42 m^3	Macroencapsulation for disposal (as needed)	ICDF

GAC = granular-activated carbon
HEPA = high-efficiency particulate air
ICDF = INEEL CERCLA Disposal Facility
PFD = process flow diagram
PPE = personal protective equipment
SGAC = sulfur-impregnated granular-activated carbon

3.7 Alternative 3.b—On-Site Ex Situ Chemical Oxidation/Reduction and Stabilization with Disposal of the Primary and the Majority of the Secondary Waste Streams at the INEEL CERCLA Disposal Facility

This final alternative applies a chemical oxidation/reduction process identical to IS-CO/S, maintaining the relative benefits of contamination control in a low-temperature liquid process, while conducting the treatment ex situ in a reaction vessel designed for this application. The vessel minimizes concerns with efficient heating, mixing, and corrosion control, because it can be designed specifically to facilitate the ES-CO/S operation. Corrosion is a specific concern because of the aggressive chemistry used at slightly elevated temperatures, particularly in the presence of chlorides. As with IS-CO/S, a specific oxidant (persulfate) was identified, but other oxidants or reductants may be selected during the design phase. A simplified PFD for ES-CO/S is shown in Figure 11. The summary mass balance is the same as that shown for IS-CO/S in Table 14, and the summary waste disposition is shown in Table 16.

For this alternative, the waste from the V-Tanks is consolidated initially into three tanks by pumping the contents from Tank V-9 into Tank V-2. Then, ex situ chemical oxidation is performed in batches of "to be determined" volume, pumped sequentially out of each of the three tanks. The supernatant and sediment phases within each tank initially are mixed together using a fluidic jet mixer to produce more uniform batches within the V-Tanks prior to transfer to the reaction vessel, where the chemical oxidation reaction is to take place. The proposed mixing process involves transferring a portion of the tank waste into a small charge vessel and then discharging it back into the tank at high pressure (<60 psi) to stir up the tank contents. This process is repeated until the tank supernatant and sludge phases are mixed sufficiently. Then, the mixed tank waste is transferred to the reaction vessel using the same system that was used to mix the tank contents.

Once in the reaction vessel, the waste will be stirred vigorously. Before and during chemical oxidation, the stirred tank waste will be adjusted and maintained at a controlled pH, as necessary, to enhance the chemical oxidation reaction. The chemical oxidant will be introduced to the stirred tank in stages to allow for oxidation of tank contents in a batch-processing manner. The initial stage will focus on the VOCs; so, there is a desire to minimize the reaction vessel's temperature during this time. Later stages will focus on oxidation of the SVOCs (such as PCBs and oil components), which could require heating to ensure sufficient destruction.

During chemical oxidation, there might be significant volatilization of hazardous VOCs into the off-gas system, despite operation at lower temperature. To attempt a more complete oxidation, the volatized organics will be condensed, with the condensate recycled back to the reaction vessel. The GAC, SGAC, and HEPA filters between the condenser and the off-gas blower will be used to fully capture noncondensable hazardous off-gases and respirable particulate before their release to the environment.

Once a batch chemical oxidation is complete, the reaction vessel's contents will be transferred and mixed with cementitious grout for stabilization purposes. Stabilization will be done in the same container used for disposal. Upon removing the chemically oxidized waste from the reaction vessel, it will be recharged with another batch of well-mixed tank sludge. This continues until the entire contents of the three tanks have been oxidized and stabilized. The containerized, stabilized waste will be sampled to verify compliance with the waste acceptance criteria and will be disposed of at the ICDF. The empty tanks and surrounding soil would then be removed and disposed of at the ICDF.

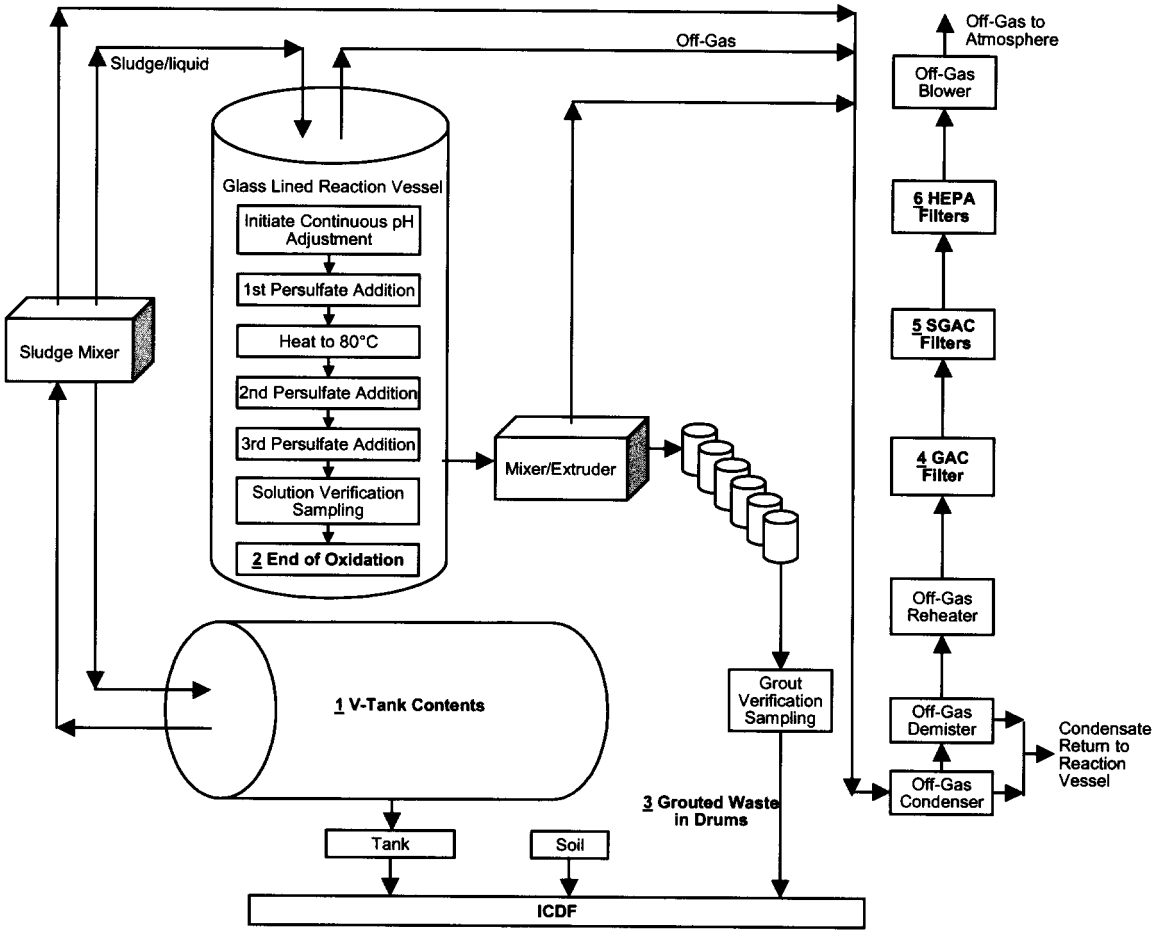


Figure 11. Alternative 3.b process flow diagram for ex situ chemical oxidation/reduction followed by stabilization.

Table 16. Summary table of generated waste, volumes, and expected disposition for ex situ chemical oxidation/reduction followed by stabilization.

Generated Waste Type	Volume	Expected Treatment	Expected Disposition
PRIMARY WASTE	**2,469 m^3**		
Grouted waste (in drums) (Item 3 in PFD)	78 m^3	None—complete	ICDF
Contaminated soil/tanks from V-Tank area of contamination	2,391 m^3	Excavated (no treatment)	ICDF
SECONDARY WASTE	**60 m^3**		
GAC filters (Item 4 in PFD)	1 m^3	Thermal	Permafix/Envirocare
SGAC filters (Item 5 in PFD)	1 m^3	None—complete	ICDF
HEPA filters (Item 6 in PFD)	0.3 m^3	Macroencapsulate for disposal	ICDF
Used PPE, consumable materials, nonrecoverable equipment	58 m^3	Macroencapsulate for disposal (as needed)	ICDF

GAC = granular-activated carbon
HEPA = high-efficiency particulate air
ICDF = INEEL CERCLA Disposal Facility
PFD = process flow diagram
PPE = personal protective equipment
SGAC = sulfur-impregnated granular-activated carbon

4. DETAILED ANALYSIS OF ALTERNATIVES

4.1 Comprehensive Environmental Response, Compensation, and Liability Act Threshold, Balancing, and Modifying Criteria

The technology evaluation process allowed a thorough evaluation of the alternatives as they relate to the CERCLA criteria. To ensure that all necessary data were collected to allow an informed decision that would minimize future implementation issues, a matrix of data needs was developed and used to guide the technology evaluation process (DOE-ID 2002a).

To decide on a new remedial alternative for the V-Tanks, the three Agencies agreed to use a CERCLA-based decision support model, which was developed for a similar treatment decision at Waste Area Group 7 on the INEEL, as an aid in selecting a preferred alternative. The criteria were evaluated by inputting preconceptual design data into the model and incorporating the value functions and weighting factors developed by the Agencies. A value function is a correlation between the range of values for a particular criterion and the range of merit values assigned to that criterion.

The results of the alternative evaluation were presented to the Agencies at a meeting held October 23 and 24, 2002. After thorough discussion, a consensus selection of a preferred alternative was made (see Section 5) for presentation in the proposed plan.

The primary CERCLA criteria are listed below, followed by a short discussion specific to the V-Tank alternative evaluations:

- Protection of Human Health and the Environment—A preliminary review of the various technologies was conducted to ensure that environmental, safety, and health concerns are addressed. This review identified the major system risks and potential controls necessary to mitigate those risks. Although this is a threshold criterion, the ability to implement these controls and their short-term effectiveness also was assessed, as described below.

- Compliance with ARARs—A preliminary review of the ARARs was completed. The selected remedy ultimately will identify all technology-specific ARARs as well as any required exceptions, waivers, or variances. A preliminary listing of ARARs for the preferred alternative is provided in Section 5.2. To establish whether each alternative meets this threshold criterion, the composition of each generated waste stream was determined and compared against disposal requirements for various facilities. All of the technology alternatives are believed to meet the applicable TSDFs' waste acceptance criteria, as described in detail in Section 3.

- Long-Term Effectiveness and Permanence—Since clean closure of the V-Tanks site is achieved following remediation, this criterion only addresses the remaining soil and associated contaminant of concern—Cs-137. Each alternative will remove the tank contents, tanks, and surrounding soil and dispose of these elsewhere, either on-Site or off-Site. Therefore, the CFTs are not a factor for this criterion. The final remediation goal for the site is equivalent for all alternatives (23.3 pCi/g Cs-137). The disposal sites for the V-Tank waste streams have conducted performance assessments previously and, from these, have established appropriate waste acceptance criteria. The next criterion specifically addresses the treatment process's effectiveness on the ability of the task contents' waste form to meet these acceptance criteria.

- Reduction of Toxicity, Mobility, and Volume through Treatment—A PFD, mass balances, and disposition pathway for each waste stream (primary and secondary) were developed for each of the seven alternatives. Such data ensure a complete assessment of this criterion. Factors used to evaluate this criterion include volume of primary and secondary waste generated and the composition of the waste forms, specifically the CFTs. The transuranic, cadmium, lead, mercury, TCE, PCB, and BEHP contaminants were selected as representative and bounding constituents associated with the specific treatment processes. The treatment process's ability to effectively achieve reduction of toxicity and mobility of these CFTs was evaluated.

- Short-Term Effectiveness—In part, this criterion was addressed by the safety review mentioned previously under Protection of Human Health and the Environment. Furthermore, it established whether the technologies could meet the overall schedule established by the V-Tank Project. Any of the technologies would be deployed under the INEEL requirements to ensure worker and public safety and, therefore, might score similarly in this area. However, the complexity and cost to ensure operation within the INEEL requirements might vary significantly. This complexity was evaluated as part of the safety aspects of short-term effectiveness.

- Cost—The Bechtel BWXT Idaho, LLC, Cost-Estimating organization prepared a life-cycle cost estimate. Past data from estimates related to the V-Tanks and similar projects were used as input to the extent possible. This includes costs for preparing the associated documentation, such as the proposed plan, ROD amendment, and remedial design/remedial action work plan. Previous estimates for soil and tank removal were used, as well as liquid removal and treatment costs. Cost for design, deployment, and operation of the treatment process was obtained through experienced cost estimators. These cost estimates were prepared, minus escalation costs, and then were discounted to net present value, using standard discount factors (see Appendix A).[b] These costs were done at a preconceptual level and are expected to be within the CERCLA guidelines of +50/-30%.

- State/Support Agency Acceptance—The State of Idaho and EPA provided early consensus on the technologies to be evaluated (DOE-ID 2002a). They also participated in a comparative analysis work session on October 23 and 24, which lead to consensus on a preferred alternative for the proposed plan. Agency approval of the regulatory measures in a future ROD amendment, which is required to support implementation of each evaluated technology, also was addressed in the October 2002 Agency meeting. Additional state/support agency acceptance will be obtained following the public comment period on the proposed plan.

- Community Acceptance—The majority of public input will be obtained during review of the proposed plan. However, to advise the public of the V-Tank Project redirection, a fact sheet (INEEL 2002b) was issued identifying the technologies selected for evaluation and allowing public feedback. This provided the project and Agencies with an early indication of potential issues and questions likely to be raised during the formal public comment period.

b. INEEL, 2002a, "INEEL Preliminary Cost Estimates 6302–6308 (Draft)," Idaho National Engineering and Environmental Laboratory, November 2002.

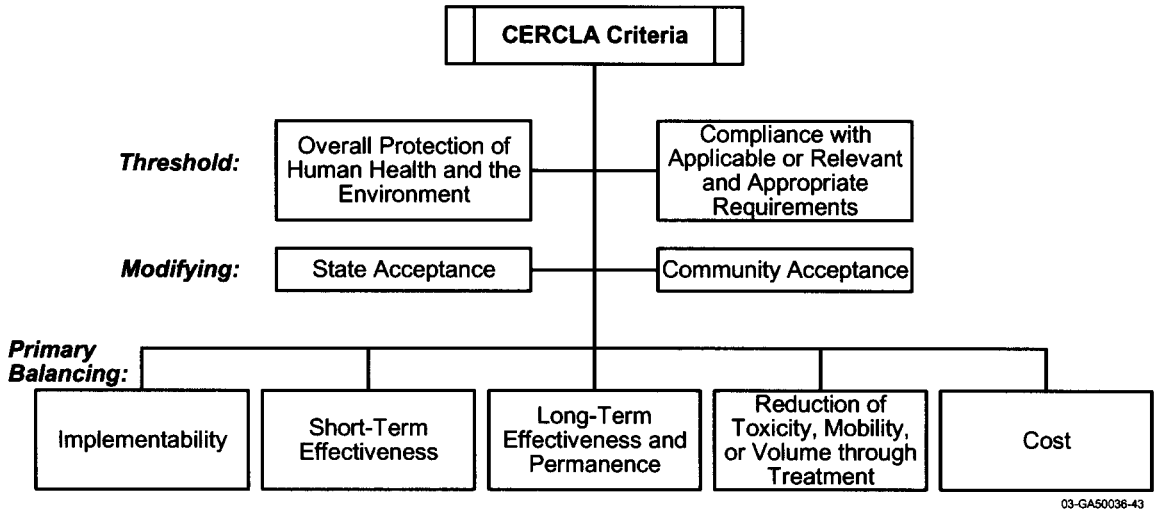


Figure 12. Comprehensive, Environmental Response, Compensation, and Liability Act criteria.

As previously discussed, the Agencies used a decision support model tailored for the V-Tanks. This model is based on the criteria identified in 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," and *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1998), which are the primary guidance documents for CERCLA. The CERCLA and the "National Oil and Hazardous Substances Pollution Contingency Plan" provide nine specified criteria, as shown in Figure 12 (40 CFR 300.430.[e][9][iii][F][1]). The CERCLA criteria are divided into three distinct groups: (1) modifying criteria, (2) threshold criteria, and (3) primary balancing criteria (40 CFR 300.430.[e][9][iii][F][1]). The modifying criteria (state and community acceptance) are not explicitly included in this decision analysis process until after the proposed plan has been released to the public for review. The threshold criteria, consisting of the overall protection of human health and the environment and compliance with ARARs, are criteria that all remedial alternatives must meet in order to be eligible for selection.

Using the "National Oil and Hazardous Substances Pollution Contingency Plan" and EPA guidance, subcriteria and evaluation measures (or value functions) are identified that allow quantitative evaluation of remedial alternative performance relative to each of the five primary balancing criteria. By applying weighting factors, the relative importance of each of these criteria is established. Scoring the remedial alternatives provides a ranking based on the criteria, subcriteria, weighting factors, and scores from the value functions. The model also allows a sensitivity analysis to be performed to determine the effects of evaluation measure score changes and changes to weighting factors on the remedial alternatives' ranking.

For the V-Tanks' decision support model, the Agencies decided to include an additional evaluation measure. A small number of other remedial actions at the INEEL have, or might, generate waste comparable to the V-Tanks and may be able to utilize the same treatment process. Three such waste streams were identified, and the ability of the various alternatives to treat these waste streams was added as an evaluation measure (see Section 5.6).

A discussion of each balancing criterion and the associated subcriterion follows. For each criterion or subcriterion, a value function is provided that correlates the performance measure (input parameter on the x-axis) to a normalized value (output value from 0 [worst] to 10 [best] on the y-axis).